



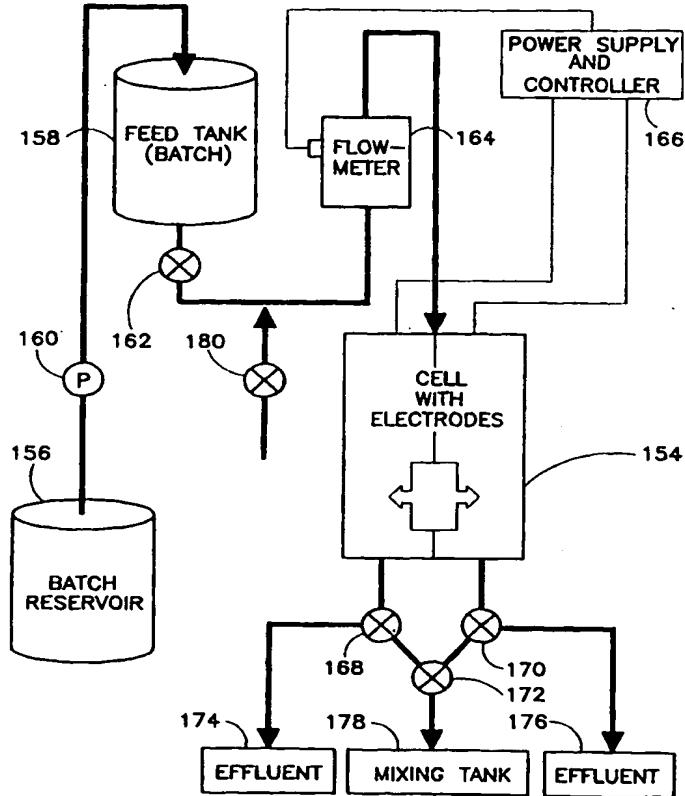
## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>C02F 1/461, 1/469</b>	A1	(11) International Publication Number: <b>WO 99/28240</b> (43) International Publication Date: 10 June 1999 (10.06.99)
(21) International Application Number: <b>PCT/US98/25114</b>		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 1 December 1998 (01.12.98)		
(30) Priority Data: 08/982,700 2 December 1997 (02.12.97) US		
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## (54) Title: METHOD AND APPARATUS FOR ADJUSTING THE pH OF A LIQUID

## (57) Abstract

An electrochemical or electrodialytic method and apparatus (154) for producing liquid of a desired pH value from input liquid of a different pH value, or for adjusting the pH of an aqueous flowable fluid, entails an electrochemical mechanism for adjusting the pH of an aqueous flowable fluid and a mechanism for then electrochemically stabilizing the adjusted pH of the fluid. The apparatus (154) includes an inlet and a channel in fluid communication with the inlet. The channel has the appearance and properties of a U-shaped connected vessel. The U-shaped connected vessel includes an inlet accumulating passage in fluid communication with an active zone between two spaced electrodes wherein the active zone has a small volume relative to the passage for accelerating fluid flow from the passage through the active zone complying with the physics of connected vessels.



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## METHOD AND APPARATUS FOR ADJUSTING THE pH OF A LIQUID

### TECHNICAL FIELD

The present invention relates to a method and apparatus for increasing or decreasing the pH of a flowable fluid. More particularly, the present invention is directed to an electrochemical method and apparatus for achieving permanent chemical changes in solutions without the 5 addition of external chemicals.

### BACKGROUND OF THE INVENTION

Various systems have been used in the preliminary treatment of fluids in municipal, industrial and agricultural processes for adjusting pH. Such systems have been used in the preliminary treatment of industrial rinsing water, the treatment of industrial waste water in 10 various production processes, and in agricultural applications, such as watering and stock breeding, and in water supply utilities. Many such processes utilize chemical reagents resulting in great inconvenience in operation and large amounts of solid deposits as a result of pH changes. Also noted have been inaccuracy in predicting and obtaining pH values.

Alternatively, electrochemical systems have been used. These systems generally include 15 the steps of flowing a liquid through inter-electrode spaces, defining cathodic and anodic zones by means of a membrane and running a current connection to the zones to effect a pH exchange upon the liquid. Examples of such a system is disclosed in U.S. Patent No. 4,936,962 to Hatzidimitriu issued June 26, 1990. The Hatzidimitriu system provides a process to adjust the acidity of a flowable fluid by electrodialysis in a cell containing membrane pairs comprising a 20 bipolar membrane and an ion selective membrane. U.S. Patent No. 4,391,680 to Mani et al., issued July 5, 1983, discloses a two-compartment water splitter having alternating cation and bipolar membranes used to remove alkali metal cations from an aqueous alkali metal chloride

solution to produce an acidified salt solution. U.S. Patent No. 4,284,492 to Karn, issued August 18, 1991, discloses a reverse osmosis electrodialysis assembly having osmotic membranes of anionic-cationic bilaminate ion-exchange composition and having electrodes supplying electrical current which effect water splitting at the membrane surfaces to produce acidity in an osmotic feed stream to prevent salt precipitation. Various other patents have issued relating to the use of two-compartment or multi-compartment electrodialysis water splitters and methods of using the same.

A problem has arisen because there is a lack of stability in the electrodialytically produced fluid having the adjusted pH resulting from processing. Also, prior art systems have low efficiency due to the high power consumption, non-uniformity of acidity change over a whole volume, destruction of liquid in the zone of electrode location, low accuracy of acid change, and inadequate ecological reliability of the process.

It is therefore desirable to develop an electronic system for adjusting the pH of an aqueous flowable fluid having an increased efficiency level of the process of pH change, reduction of specific power consumption for the process pH change, increase in ecological purity of the process, and an increase of accuracy level of the pH change process.

#### SUMMARY OF THE INVENTION

The present invention provides an electrochemical or electrodialytic method and apparatus for producing liquid of a desired pH value from input liquid of a different pH value. This result is achieved without the addition of any chemical composition to the liquid.

In the accordance with the present invention, there is provided a process for adjusting the pH of an aqueous flowable fluid by electrochemically adjusting the pH of an aqueous flowable fluid and then electrochemically stabilizing the adjusted pH of the fluid. The adjusting of the pH

is accomplished by guiding fluid between two electrodes, while the stabilizing of the adjusted pH is accomplished by directing the fluid having the adjusted pH over or past an edge of an electrode. The enhanced electrodialytic and/or electrochemical activity in the area of the edge is believed to stabilize the pH change.

5 As used herein, the term "adjust" or "adjusting" or "adjusted" when applied to the pH of a fluid refers to a change or alteration in the pH of the fluid. As used herein, the term "stabilize" or "stabilizing" or "stabilized" means that a fluid of adjusted pH is treated or acted upon to impart an enhanced degree of permanence to the adjusted pH level.

The present invention further provides a process for adjusting the pH of an aqueous  
10 flowable fluid by supplying a fluid through a channel in the form of a U-shaped connected vessel and dividing the fluid into two branches including an inlet accumulating passage leading to an action zone between two electrodes wherein the action zone has a smaller volume relative to the inlet accumulating passage and accelerating the fluid flow from the inlet accumulating passage through the action zone complying with the physics of connected vessels. Generally, the  
15 accumulating passage is in a first leg of a U-shaped vessel while the action zone is in the other leg of the U-shaped vessel. Preferably, the fluid to be treated is introduced into an upper end of the first leg and subsequently flows upwardly at a high velocity in the second leg.

The present invention further provides a device for adjusting the pH of an aqueous flowable fluid, the device including electrochemical adjusting means for adjusting the pH of the  
20 fluid and electrochemical stabilizing means for stabilizing the adjusted pH of the fluid. The electrochemical adjusting means preferably comprises a space or action zone between two electrodes, more specifically a cathode and an anode. A membrane may be disposed between the electrodes to form a high-pH passageway and a low-pH passageway. The fluid to be treated

thus flows past electrode and membrane surfaces in the high-pH passageway and the low-pH passageway.

The present invention also provides a device for adjusting the pH of an aqueous flowable fluid, the device including an inlet and a channel in fluid communication with the inlet. The 5 channel has the appearance and properties of a U-shaped connected vessel. The U-shaped connected vessel includes an inlet accumulating passage in fluid communication with an action zone between two spaced electrodes. The action zone has a small volume relative to the passage for accelerating fluid flow from the passage through the action zone complying with the physics of connected vessels.

10 Accordingly, a liquid processing method in accordance with the present invention utilizes an electrochemical cell assembly having a pair of electrodes disposed adjacent to one another to define therebetween an action zone and additionally having an ion-permeable membrane disposed in the action zone between the electrodes for dividing the action zone into a first passageway or chamber and a second passageway or chamber. Pursuant to the method, a first 15 liquid stream is guided through the first passageway, the first liquid stream having an initial pH value, and a second liquid stream is directed through the second passageway. During this guiding and directing, a potential difference is generated across the electrodes. The guiding of the first liquid stream, the directing of the second liquid stream, and the generating of the potential difference across the electrodes are coordinated or controlled so that an effluent liquid. 20 stream at an outlet of the electrochemical cell assembly has a desired pH value different from the initial pH value.

The effluent liquid stream of the desired pH value may be the first liquid stream or the second liquid stream after their traversal of the first passageway or second passageway,

respectively. Alternatively, where the the first liquid stream and the second liquid stream are independent, those streams may be combined to yield the effluent stream. In that case, the first liquid stream and the second liquid stream have substantially different pH values after respectively traversing the first passageway and the second passageway, with the desired pH 5 being between those substantially different pH values.

In accordance with another feature of the present invention, the coordinating or controlling step includes varying a flow rate of at least one of the first liquid stream and the second liquid stream. The varying of the flow rate may include diverting at least a portion of one of the first liquid steam and the second liquid from a downstream end of the action zone to an 10 inlet end of the first passageway or the second passageway. In that case, the varying of the flow rate may further includes operating a pump to move the portion from the downstream end of the action zone to the inlet end.

The variation in flow rate may be implement by operating a pump and/or by actuating a valve.

15 Pursuant to another feature of the present invention, the method further comprises automatically measuring a pH of a liquid stream at an outlet end of the electrochemical cell assembly and automatically comparing the measured pH to a preselected reference pH value. The varying of the flow rate is implemented in response to the comparing of the measured pH to the preselected reference pH value.

20 Where the first liquid stream and the second liquid stream are both derived at least in part from a third liquid stream at an inlet of the eletrochemical cell assembly, the method further comprises dividing the third liquid stream to form at least portions of the first liquid stream and the second liquid stream. Where the first stream and the second stream are both entirely derived

from the third liquid stream, the first stream and the second stream of course have the same initial pH value.

In a particular embodiment of the present invention, the first liquid stream and the second liquid stream are along the same flow path through the electrochemical cell assembly, the second liquid stream being downstream of the first liquid stream. Thus, the first liquid stream and the second liquid stream are the same stream, viewed at different points along a flow path. The 5 liquid flows through one passageway of the electrochemical or electrodialytic cell and subsequently flows through the other passageway thereof. In this embodiment utilization of all of the liquid is ensured.

10 In accordance with another feature of the present invention, the method further comprises stabilizing a pH level of at least one of the first liquid stream and the second liquid stream at an outlet end of the action zone. The stabilizing is effectuated by guiding the one stream so that a substantial amount of the one stream flows over an electrode edge after pH adjustment of the one stream in the respective first passageway or second passageway. This edge is maintained at a 15 common electrical potential with one of the electrodes.

As used herein, the term "adjust" or "adjusting" or "adjusted" when applied to the pH of a fluid refers to a change or alteration in the pH of the fluid. As used herein, the term "stabilize" or "stabilizing" or "stabilized" means that a fluid of adjusted pH is treated or acted upon to impart an enhanced degree of permanence to the adjusted pH level.

20 In accordance with an additional feature of the present invention, the method further comprises feeding an incoming stream of liquid to an accumulating chamber upstream of the action zone, the accumulating chamber having a substantially greater volume than each of the first passageway and the second passageway. In this way, liquid passing to the action zone is

automatically accelerated pursuant to the principles of hydraulic flow.

The coordinating or controlling step may include varying a characteristic of electrical power applied to the electrodes. The current or the voltage may be varied. More particularly, the amplitude or intensity of the voltage or current may be varied. Where the voltage or current

- 5 includes an a-c component, the variable characteristic or characteristics may include the period or frequency, the pulse shape, the interval between pulses, etc.

A liquid processing apparatus in accordance with the present invention comprises an electrochemical cell assembly having a pair of electrodes disposed adjacent to one another to define therebetween an action zone and additionally having an ion-permeable membrane 10 disposed in the action zone between the electrodes for dividing the action zone into a first passageway and a second passageway. A first flow guide extends to an inlet end of the first passageway for delivering to the first passageway a first liquid stream having an initial pH value. A second flow guide extends to an inlet end of the second passageway for delivering to the second passageway a second liquid stream. A voltage source operatively connected to the 15 electrodes to apply a potential difference across the electrodes. A flow control component is operatively connected to at least one of the electrochemical cell assembly, the first flow guide and the second flow guide for coordinating the first liquid stream, the second liquid stream, and the potential difference so that an effluent liquid stream at an outlet of the electrochemical cell assembly has a desired pH value different from the initial pH value.

- 20 The flow control component may include a flow rate control element for varying a flow rate of at least one of the first liquid stream and the second liquid stream. The flow rate control element may be a valve and/or a pump which is operative to selectively divert at least a portion of one of the first liquid steam and the second liquid from a downstream end of the action zone to

an inlet end of one of the first passageway and the second passageway.

The apparatus may further comprise a pH detector disposed at an outlet end of the electrochemical cell assembly for automatically measuring a pH of a liquid stream at the outlet end. The flow rate control element is operatively connected to the pH detector for varying the  
5 flow rate in response to a pH value measured by the pH detector.

The apparatus defined in claim 14, further comprising channels connected to the electrochemical cell assembly dividing an inlet liquid stream into the first stream and the second stream upstream of the action zone, the first stream and the second stream both having the initial pH value.

10 Pursuant to a particular embodiment of the present invention, the first liquid stream and the second liquid stream are along the same flow path through the electrochemical cell assembly, the second liquid stream being downstream of the first liquid stream. Thus, the first liquid stream and the second liquid stream are the same stream, along different segments of the flow path. In this case, the effluent stream is the same as the first stream and the same as the second  
15 stream.

Preferably, at least one of the electrodes has an edge which is positioned along the flow path of a respective liquid stream for stabilizing a pH level of that stream at an outlet end of the action zone.

An accumulating chamber may be provided upstream of the action zone and in fluid  
20 communication therewith, the accumulating chamber having a substantially greater volume than each of the first passageway and the second passageway. In most cases, the accumulating chamber will have a substantially greater volume than the entire action zone.

A device for treating a flowable fluid comprises, in accordance with the present

invention, a pair of electrodes disposed adjacent to one another to define therebetween a flow path, electrically conductive connectors operatively coupled to the electrodes for enabling generation of a potential difference across the electrodes to electrochemically adjust the pH of a solution flowing along the path between the electrodes, and a flow guide directing the solution 5 along the path so that a substantial amount of the solution flows over an electrically conductive edge after pH adjustment of the solution, the edge being at a common electrical potential with one of the electrodes.

This device may be further provided with a flow control assembly for controlling a volume flow rate of the solution along the path. The flow control assembly may include a pH 10 detector disposed downstream of the electrodes.

Preferably, a membrane is disposed between the electrodes to partition the path into two separate flow zones. In that case, the flow control assembly includes a first element such as a pump and/or a valve for adjusting a volume flow rate through one of the flow zones and a second element such as a pump and/or a valve for adjusting a volume flow rate through another of the 15 flow zones.

Wherein the one flow zone has an input end and an output end, the device further comprises at least one flow channel extending back from the output end to the input end and a flow rate adjuster along the flow channel for varying a volume flow rate of pH adjusted liquid along the channel from the output end to the input end. The flow control assembly is operatively connected to the flow rate adjuster for determining the operation thereof. 20

A device for treating a flowable fluid comprises a pair of electrodes disposed adjacent to one another to define therebetween an action zone, an ion-permeable membrane disposed in the action zone between the electrodes for dividing the action zone into two passageways or

chambers, a first pair of channels connected to the passageways or chambers to deliver separate streams of fluid to the passageways or chambers, and electrically conductive connectors operatively connected to the electrodes for enabling generation of a potential difference across the electrodes to electrochemically work on a solution flowing along a path extending through 5 the action zone between the electrodes.

A flow control element may be disposed along the path for adjusting a volume flow rate through one of the passageways or chambers. The device may further comprise a pH detector disposed downstream of the electrodes, the pH detector being operatively connected to the flow control element. The device may further comprise (1) at least one flow channel extending back 10 from an output end of the one passageway to an input end of the same passageway and (2) a flow rate adjuster along the flow channel for varying a volume flow rate of pH adjusted liquid along the flow channel from the output end to the input end. Alternatively, the device may further comprise at least one flow channel extending back from the output end of one passageway to the input end or the other passageway.

15 A method for disinfecting a liquid utilizes, in accordance with the present invention, an electrochemical cell having a pair of electrodes disposed adjacent to one another to define therebetween an action zone and additionally having an ion-permeable membrane disposed in the action zone between the electrodes for dividing the action zone into two passageways or chambers. The method comprises feeding a solution to an inlet of first one of the passageways, 20 guiding the solution from an outlet of the first one of the passageways to an inlet of a second one of the passageways, and generating a potential difference across the electrodes during feeding of the solution to the first one of the passageways or chambers and during the guiding of the solution from the outlet to the inlet of the second one of the passageways or chambers.

The present invention also contemplates the treatment of a liquid and particularly the adjustment of pH wherein only one electrode is used. Generally, in this case the membrane is also omitted. The solution to be treated is constrained to flow along an at least partially upward path past the electrode and in contact therewith.

5       The present invention provides an electrochemical or electrodialysis system for adjusting the pH of an aqueous flowable fluid having an increased efficiency level of the process of pH change. Specific power consumption for the process pH change is reduced. In addition, accuracy level of the pH change process is increased while ecological detriment is minimized, if not eliminated.

10      The high speed of the fluid through the action zone between the two electrodes has the effect of cooling the electrodes. The cooling of the electrodes enables an increase in electrical current density and concomitantly enhanced efficiency of operation. In addition, slime deposits on the electrode surfaces and in the action are reduced by the rapid passage of the liquid. Another advantageous effect of the rapid fluid movement is to inhibit the formation of an idle 15 zone along the electrodes. Liquid held in an idle zone by surface tension would form a stagnant liquid layer which would work against effective ion migration. In addition, such an idle zone would increase the resistance to the motion of liquid through the action zone and thus increase energy requirements for moving the fluid.

20      The liquid is guided through the action zone between the electrodes so as to uniformly distribute the liquid and thus facilitate a uniform electrochemical action on the moving liquid.

      The high speed of the fluid through the action zone between the two electrodes results in a reduction in electrical resistance by decreasing the amount of turbulence and number of air bubbles formed. Furthermore, cavitation on the edges of the electrodes is inhibited.

An electrodialysis system in accordance with the present invention can be used for changing or adjusting the pH of waste fluids under different conditions, as well as for the preparation of aqueous solutions for chemical and industrial processes.

Because pH is such a fundamental water quality parameter that it is frequently monitored  
5 and requires adjustment in waters, waste waters, as well as in chemical and industrial processes, the electrodialysis system described herein will have wide applications. The system of the present invention offers an environmentally attractive, safe alternative technology to the potentially hazardous purchase, use, storage, and disposal of strong reactive chemicals such as acids and bases.

10 An electrodialysis system in accordance with the present invention can have numerous uses, for example, in the production of pH balanced water without the use of chemicals in agricultural applications, in changing the environment of insects for insect control purposes, in agricultural disinfection for washing crops and the udders of milking cows, in chlorination, in medical disinfection. Other applications, requiring a high pH, include the production of an  
15 aqueous solution as an emulsifying agent, for instance to clean oil from automobile parts. Further applications include the removal of plaque, the production of citric acid, the production of activated water, the breaking up of cyanide, and the softening of water (by raising the pH).

#### BRIEF DESCRIPTION OF THE FIGURES

Other advantages of the present invention will be readily appreciated as the same  
20 becomes between understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a front elevational view, partly broken away, of a device for adjusting the pH of a liquid, in accordance with the present invention;

Fig. 2 is a rear elevational view of the device of Fig. 1;

Fig. 3 is a longitudinal cross-sectional view, taken along line III-III in Fig. 1 of a U-shaped housing electrochemical processing elements;

Fig. 4 is a longitudinal cross-sectional view, taken along line IV-IV in Fig. 3;

5 Fig. 5 is a partial cross-sectional view, on a larger scale, also taken along line IV-IV in Fig. 3;

Fig. 6A is a side elevational view of the device of Figs. 1 and 2, additionally showing a component for extracting gases;

Fig. 6B is a cross-sectional view of the gas extraction component of Fig. 6A;

10 Fig. 7 is an exploded cross-sectional view partially similar to Fig. 4, additionally showing, on a larger scale, a liquid pretreatment unit upstream of the U-shaped electrochemical processing housing;

Fig. 8 is an elevational view of a collection system for channeling pH-adjusted fluids at an outlet end of the U-shaped electrochemical processing housing of Figs. 4 and 5;

15 Fig. 9 is basically a flow diagram of a batch-type system or device for adjusting the pH of a liquid, in accordance with the present invention.

Fig. 10 is a flow diagram of a continuous-type system or device for adjusting the pH of a liquid, in accordance with the present invention.

20 Fig. 11 is a flow diagram of another continuous-type system or device for adjusting the pH of a liquid, in accordance with the present invention.

Fig. 12A is a graph illustrating pH as a function of flow rate through an electrochemical or electrodialytic cell in accordance with the present invention.

Fig. 12B is a graph illustrating pH change as a function of flow rate through an

electrochemical or electrodialytic cell in accordance with the present invention.

Fig. 12C is a graph illustrating conductivity of a fluid as a function of flow rate of the fluid through an electrochemical or electrodialytic cell in accordance with the present invention.

Fig. 12D is a graph illustrating applied power as a function of flow rate through an  
5 electrochemical or electrodialytic cell in accordance with the present invention.

Figs. 13A-13F are graphs illustrating pH of a fluid as a function of concentration of various types of ions in the fluid, before and after passage of the fluid through an electrochemical or electrodialytic cell in accordance with the present invention.

Figs. 14A-14F are graphs illustrating pH change as a function of concentration for the  
10 various ion types respectively depicted in the graphs of Figs. 13A-13F.

Figs. 15A-15F are graphs illustrating conductivity as a function of concentration for the various ion types respectively depicted in the graphs of Figs. 13A-13F.

Figs. 16A-16F are graphs illustrating pH as a function of ion activity for the various ion types respectively depicted in the graphs of Figs. 13A-13F.

15 Fig. 17 is essentially a flow diagram of another system for adjusting the pH of a liquid, in accordance with the present invention.

Fig. 18 is a schematic isometric view of an electrochemical or electrodialytic cell assembly in accordance with the present invention.

Fig. 19 is a cross-sectional view taken along plane XIX-XIX in Fig. 18 and shown as a  
20 mirror image (left and right reversed).

Fig. 20 is a partial cross-sectional view similar to Fig. 19, showing a modification of the electrochemical or electrodialytic cell assembly of Figs. 18 and 19.

Fig. 21 is a schematic isometric view of an electrode shown in Fig. 20.

Fig. 22 is a partial cross-sectional view taken along line XXII-XXII in Fig. 21, showing a recess in the electrode of Fig. 21.

Fig. 23 is a partial cross-sectional view similar to Fig. 22, illustrating a perforation which may be provided in the electrode of Fig. 21.

5 Fig. 24 is a partial cross-sectional view similar to Fig. 22, illustrating an alternative recess shape which may be provided in the electrode of Fig. 21.

Fig. 25 is a cross-sectional view similar to Fig. 19, showing another electrochemical or electrodialytic cell assembly in accordance with the present invention.

10 Fig. 26 is a schematic isometric view of an electrode contained in the electrochemical or electrodialytic cell assembly of Fig. 25.

Fig. 27 is a partial cross-sectional view taken along line XXVII-XXVII in Fig. 26, showing a projection on the electrode of Fig. 26.

Fig. 28 is a partial cross-sectional view similar to Fig. 27, illustrating a modified projection which may be provided on the electrode of Fig. 26.

15 Fig. 29 is a partial cross-sectional view similar to Fig. 27, illustrating an alternative projection which may be provided on the electrode of Fig. 26.

#### DETAILED DESCRIPTION OF THE INVENTION

A device made in accordance with the present invention is generally shown at 10 in the drawings. The device is an assembly for adjusting the pH of an aqueous flowable fluid and, more 20 particularly, changing the pH of a fluid to a desirable level. This is accomplished by an electrode dialysis or electrochemical method. Most generally, the present invention provides a device including an electrochemical adjusting mechanism for adjusting the pH of a fluid in combination with a mechanism for stabilizing the adjusted pH of the fluid. Moreover, the device incorporates

a U-shaped channel in fluid communication with an inlet, where the channel is particularly implemented as a vessel having two interconnected chambers disposed as respective legs of a U. The entire U-shaped channel or vessel is referred to herein as a U-shaped connected vessel. The U-shaped connected vessel includes an inlet accumulating passage or chamber (one leg of the U) 5 in fluid communication with an action zone or chamber (another leg of the U) between two spaced electrodes. The action zone has a smaller volume relative to the accumulating passage, whereby fluid flow from the accumulating passage through the action zone is accelerated in accordance with the physics of fluid flow. In this manner, the present invention provides a novel mechanism for producing a stable fluid of a desired pH which is different from the pH of the 10 fluid entering assembly. Moreover, unlike prior art assemblies, there is less power consumption due to the increased efficiency gained by the hydrodynamic effects described in detail below.

In Fig. 1, a housing is generally indicated at 12. The assembly is supported within a frame 14. Outside of the housing 12, an inlet 16 from a fluid source is in fluid communication with a pump 18.

15 Preferably, the pump 18 is a centrifugal water pump known to those skilled in the art. As better shown in the rear view, Fig. 2, the pump 18 pumps the fluid through piping 20 to two mechanical filters 22, 24. Filters 22, 24 comprise disk elements and are semi-automatic self-cleaning filters known to those skilled in the art. These filters remove particulate matter from the fluid which would otherwise have the potential for clogging the system.

20 Various regulating valves can be disposed throughout the fluid flow system. For example, a regulating valve 26 is provided downstream from the mechanical filters 22, 24. The regulating valve 26 controls the amount of liquid inlet flow into the housing 12. It also closes liquid passage through the system for the purpose of cleaning the mechanical filters 22, 24. An

inline flow meter 28 is used for the conventional purpose of monitoring flow through the system. The meter 28 is in fluid communication with a liquid inlet pipe 30. The liquid inlet pipe 30 has a larger cross-section than the downstream piping in order to provide a larger volume of fluid to the entrance of the housing 12.

5 As best shown in Fig. 1, a control or command unit 32 is mounted on the frame 14. The unit 32 includes a processor, electrical components, and the like well known to those skilled in the art for controlling the automatic operation of the assembly. For example, control or command unit 32 may be programmed to vary the voltage and/or current characteristics to achieve a desired pH change. Various aspects of the assembly can be automated, such as the  
10 activation state of the pump 18 as well as the electrically controlled valving. As shown in Figs. 1 and 2, the valving is manually controlled but can alternatively or additionally be controlled electrically.

A power supply 34 is also mounted on the frame 14. The power supply 34 provides electrical potential (negative and/or positive) to the electrodes which are described below. The  
15 power supply advantageously comprises two separate voltage sources, one for each electrode. Thus, the potential of each electrode can be regulated independently of the other electrode. Appropriate electrical connections are made between the control unit 32, power supply 34, and the remainder of the unit, as well known in the art.

Fig. 3 shows a cross-section of the housing 12 taken along line III-III in Fig. 1. The  
20 housing 12 contains an internal channel in fluid communication with inlet 30, the channel having the appearance and properties of a U-shaped connected vessel. The U-shaped connected vessel includes a vertically extending inlet accumulating passage or chamber 36 having a first predetermined volume. Fluid accumulates in this chamber prior to entry into a vertically

extending reaction chamber 38. As best shown in Figs. 4 and 5, the reaction chamber 38 includes two electrodes generally shown at 40, 42 supported by current lead connectors in form of rods 44, 46, respectively to the top plate 48 of the housing 12. Disposed between the electrodes 40, 42 is a semi-permeable membrane 50, which is an electrically neutral membrane, 5 well known in the art. The finer the weave of membrane 50 and the thicker the membrane, the better, because there is less flow exchange without affecting ion exchange.

Between electrodes 40, 42 is an action zone which is divided by the membrane 50 into two sub-chambers 41, 43. The sub-chambers 41, 43 in combination have a much smaller volume than the inlet accumulating passage 36. Additionally, the accumulating passage 36 and the 10 action-zone sub-chambers 41, 43, in combination, form a U-shaped connected vessel.

Accumulating passage 36 forms one leg of the U-shaped vessel, while the action zone between electrodes 40, 42 forms another leg of the U-shaped vessel. Due to the relatively large volume of the accumulating passage 36 relative to the action zone, fluid flowing outwardly through the accumulating passage 36 and around and up through the action zone accelerates through the 15 action zone, in compliance with the physics of fluid flow. This hydro-dynamic effect greatly increases the efficiency of the system while requiring less energy consumption as compared with prior art assemblies. Hence, this aspect of the invention provides increased efficiency of operation to a significant degree.

As stated above, as the fluid flows through the action zone, the electrodes 40, 42 in 20 combination with the neutral membrane 50 act electrochemically to effectively acidify the fluid adjacent one electrode (the cathode) while producing alkali fluid adjacent the other electrode (the anode), on opposite sides of the membrane. In other words, the lead connectors 44, 46 each carry an opposite charge from a power source schematically shown at 52 contained within

housing case 54 where the rods 44, 46 are connected electrically to the power source at 56, 58 respectively. The charges carried to the respective electrodes 40, 42 oppositely charge those electrodes so that the electrodes 40, 42 and the membrane 50 together act as an electrodialysis system to effectively split the water. Thus, the system provides a mechanism for 5 electrochemically adjusting the pH of the fluid flow passing therethrough.

As illustrated in Fig. 5, each of the electrodes 40, 42 includes a respective vertically disposed portion 60, 62 each of which is provided at a lower end with a respective bent portion 64, 66 proximate to an entrance from the passage 36 to the action zone. The electrodes 40, 42 further include respective upper horizontal portions 68, 70, each connected to the power source 10 52 through the rods 44, 46. Each of the electrodes 40, 42 has a peripheral edge 72, 74 over or past which all of the fluid with the adjusted pH flows. These edges generate an enhanced electrical field and thereby provide a stabilizing mechanism for fluid after passing thereof through the action zone between electrodes 40, 42. The fluid passes from the action zone over the horizontal surfaces 68, 70 of the electrodes 40, 42 and then over the edges 72, 74, thereby 15 implementing an "edge effect" on the fluid having the adjusted pH. The enhanced electrical power and/or electrochemical activity induced in the moving fluid in the area of the edge 72, 74 is believed to stabilize the changed pH of the fluid. It is to be noted that this stabilization of the adjusted pH may be implemented additionally or alternatively by edges disposed upstream of the peripheral edges 72, 74. For example, holes or perforations may be formed in the electrodes 40, 20 42, particularly in the downstream portions thereof. (In some cases, the fluid may be constrained to flow through one or more perforations to an outlet of the electrochemical or electrodialytic cell.) Alternatively, each electrode 40, 42 may be formed as a series of electrodes disposed one after the other along the direction of fluid flow. In that case, the trailing edges (and

possibly some of the leading edges) of the consecutive electrodes serve to stabilize the changes in pH. The stabilizing effect of edges 72, 74 is believed to be enhanced because the pH-adjusted fluid is constrained by gravity to flow partially around the edges, and not merely along a linear flow path past the edges. Thus, the pH-adjusted water is subjected to an increased extent to the power saturation and enhanced electrochemical activity induced in the water in the region of the edges 72, 74. Of course, the same end result of stabilizing the adjusted pH level is attainable, in a linear flow situation, by increasing the electrical power per unit volume of the pH-adjusted water. This increase may be effectuated by reducing the flow rate of the fluid or by increasing the electrical current. It is to be noted, however, that constraining the pH-adjusted water to flow 10 partially around the electrode edges 72, 74 is an especially cost effective way to stabilize the adjusted pH levels.

Where the adjusted-pH liquid is flowing along a linear path past electrode edges, it is desirable for pH-stabilization purposes to constrain the liquid spatially by restricting the width of the flow path in the region of the electrode edges so that the distance of any particle of liquid 15 from the edge is limited. The smaller this distance, the greater the stabilization effect of the electrode edge. An advantageous spatial constraint is naturally achieved where the flow path induces laminar flow as in subchambers 41, 43 of the action zone between electrode portions 60, 62. To that end, the distance between electrodes 40 and 42, particularly between electrode portions 60 and 62, thereof should be no greater than 10 cm.

20 As is demonstrated by experimental evidence set forth below, the pH-changed fluid is stabilized for a much longer period of time as compared to chemical techniques or prior art electrochemical pH-modification techniques. The present invention provides an increase in the efficiency of acidity change by reducing specific power consumption, this reduction arising at

least in part from utilization of the U-shaped connected vessel. Also, ecological purity is increased in the process, while increasing the process precision without changing and adding other substances to the liquid by utilizing the action zone in combination with the edge effect.

As shown in Figs. 4 and 5, at least one of the electrodes 40 can include a substantially vertical downward extension 76 for providing a further stabilizing effect on the pH adjustment. Arrows 78, 80 in Fig. 4 show the fluid flow pattern as the fluid falls from horizontal surface 68 to contact the edge 72 of the extension 76 of the electrode 40. Either one of the electrodes, the positive or negative, or both electrodes, or neither of the electrodes can be so extended.

As best shown in Fig. 4, electrode extension 76 is inclined inwardly towards the vertical electrode portions 60, 62. Electrode extension 76 is provided at a downstream end with an outwardly extending surface or lip 82. Electrode edge 72 defines the downstream end of lip 82 which acts to catch the fluid flow as shown by arrow 80 so that all of the fluid flowing over the horizontal surface 68 of the electrode 40 flows over edge 72, thereby ensuring implementation of the edge effect.

As best shown in Fig. 5, the flow of the fluid over the horizontal surfaces 68, 70 of the electrodes 40, 42 brings the fluid in direct contact or direct proximity with the lead connectors 44, 46. The lead connectors 44, 46 are non-insulated and preferably made from the same material as the electrode portions 60, 62. Current carried by the lead connectors 44, 46 can affect the fluid flowing thereby. It has been found that the lead connectors 44, 46 provide additional power saturation for additionally power saturating the fluid flow thereby further effectuating the pH change and stabilization of the pH change.

Preferably, the lead connectors 44, 46 are streamlined with respect to the fluid flow. Both the electrodes 40, 42 and lead connectors 44, 46 are preferably made from current

conducting material insoluble in liquid of any pH value. Such materials include stainless steel, titanium and carbon composites. The latter is particularly effective in reducing pH, presumably because the material acts as an oxygen scavenger. The electrode extension 76 is preferably made from chemically more inert material. Examples of such materials are titanium, titanium with 5 platinum coating, titanium with palladium coating, and other materials known in the electrode art.

Preferably, the distance between the electrode portions 60, 62 is equal to one to two millimeters while operating without a membrane (preferable in some applications) and four to six millimeters while operating with a membrane. Such a distance allows for acceleration of the 10 fluid flow through the action zone between the electrodes 40, 42 to a speed of two meters per second. Additionally, it is preferred that the bent portions 64, 66 of electrodes 40, 42 are oriented at an angle of 30° to 45° relative to the vertical portions 60, 62 of the electrodes.

Gas and aerosol outlet ports 84, 86 are provided in the housing 12 at a location above the horizontal portion 68, 70 of the electrodes 40, 42, as illustrated in Fig. 5. The ports 84, 86 are 15 located so as to be able to remove the gases from above the action zone in a direction perpendicular to the direction of the fluid movement in the action zone. As shown in Fig. 6A, a filter assembly 87 is in fluid communication with the outlet 84. Assembly 87 includes a housing 88 provided with air pressure piping 90 and vacuum creating piping 92 for extracting gases from 20 the treatment zone within the housing 88.

The housing 88, shown on a larger scale in Fig. 6B, contains a filter including aluminosilicate granulated material. More specifically, natural granulated clinoptilolite is used as a filler, indicated at 94. The filler is contained within cylinders 96, 98. The gases and aerosols are guided to cylinders 96, 98 in a tangential direction, through conical settling basins

97, 99 formed by plates 100, 102, 103, 104 disposed so as to cause turbulence of the gas or aerosol entering housing 88. Plates 102 and 104 include ring-shaped portions 106 and 108 pooling condensates of gases passing through the housing 88. Thus, the system provides two filtration cylinders 96, 98 containing the clinoptilolite filler 94 as well as a turbulent operating system. The gases are guided to the cylinders 96, 98 of the filter in a tangential direction, through the conical settling basins 97, 99 with a vertical effect.

The assembly 87 can also contain a cloth filter (not shown) for conventional filtration of air, aerosols, and fluids therethrough.

Prior to introduction of liquid to the pH balancer, treatment of the liquid is required or 10 recommended in order to protect electrodes 40, 42 and prevent scale formation and sedimentation of hard salts on the active surface of the negative electrode (cathode). In addition, the electrodialysis process causes a plating of the electrode even though the heavy metal concentration may be relatively low. Accordingly, effort must be made eliminate or minimize this plating process.

15 The plating process takes place due to the small distance between electrode portions 60 and 62 and the presence of some of the following elements in the water: Ca, Mg, K, Fe etc. The plating process is enhanced at the edges of the electrode. (The edge effect in this case is a drawback, since the plating of the electrode edges reduces the effectiveness thereof in stabilizing the pH of the liquid.) Furthermore, where the electrodes are made of titanium, the surfaces of the 20 electrodes are somewhat rough and the outstanding titanium particles tend to be plated more quickly.

For all the above reasons, a pre-treatment device is contemplated for preventing or inhibiting plating on the surface and edges of the electrodes 40, 42. It is known that contact

between liquid and high potential metals impedes the sedimentation process and that if the period of contact is prolonged, sedimentation of salts or scale formation is minimized. Therefore, the pre-treatment device includes metal-coated ceramic spheres disposed in contact with the water stream, the spherical shape or the coated ceramic particles serving to maximize contact with

5 water, thus eliminating scale formation. It is also known that if the site of contact between salts in liquid and coated spheres is subject to strong magnetic field, sedimentation of salts is further reduced and may arrest electrode plating. The pre-treatment of liquid entering the pH-adjustment device is performed to arrest or inhibit the sedimentation of salts and the electro-chemical plating of the cathode (negative charged electrode).

10 A pre-treatment system is generally shown at 112 in Fig. 7. The pre-treatment system 112 is shown on an enlarged scale relative to the housing 112. The pre-treatment system 112 includes a fluid inlet pipe 114 and fluid outlet pipe 116 and a central housing 118. The inlet pipe 114 is provided with holes 120, while the fluid outlet pipe 116 is formed with holes 122. Between the inlet pipe 114 and the outlet pipe 116 is a space (not separately designated)

15 containing magnetic particles 124 for treatment of the fluid passing through housing 118. The housing 118 holds granules of coated ceramic 126. The granules of coated ceramic 126 may take the form of spheres plated with multiple layers, such as copper plated with tin, tin then plated with copper, and copper then plated with silver. The spheres 126 are thus made of porous ceramic material coated with layers of copper, tin, silver and zinc. The outside layer is either

20 silver or zinc. The spheres 126 with an outside coat of silver and zinc are mixed. The liquid flowing between the spheres 126 causes turbulence (an effect similar to liquid motion while being boiled). Due to the fact that the outside coat is silver or zinc, an electrical potential of 20 to 40 millivolts is generated. This causes a chemical balance and the following advantages are

achieved:

1. No loss of energy for unwanted activities such as plating;
2. Isolation and protection of electrode's surface to prevent sedimentation and scale formation; and
- 5 3. Arresting metal plating of negative electrode.

This pretreatment system provides a contact-stabilization stratum of elements. While the liquid is passing through the contact stabilization stratum, that being the spherical ceramic granules, the fluid is also treated by the magnetic field.

As shown in Fig. 8, after passing over the edges 72, 74 of the electrodes 40, 42 the fluid 10 is collected and exits through outlets 128, 130. Appropriate valving 132, 134, 136, 138 controls outlet fluid flow. The fluid can be controlled to exit separately by closing valves 134 and 138 and opening valves 132, 136. Alternatively, valves 132 and 136 can be closed and valves 134 and 138 opened to various degrees to provide a combined flow through outlet 144. Valve 146 controls the combined flow through valve 144 and have an on/off effect. Thus, acidic and 15 alkaline stabilized fluids can be removed separately through outlets 140 and 142 or combined at various ratios by controlling the valves 134, 138 for exit through outlet 144.

Based on the above, the present invention provides a novel process for adjusting the pH of aqueous fluids by electrochemically adjusting the pH of an aqueous fluid and then electrochemically stabilizing the adjusted pH of the fluid. The stabilizing is effected by flowing 20 the fluid having the adjusted pH over an edge 72, 74 of electrodes 40, 42. More specifically, the process proceeds initially by operating pump 18 to move fluid through mechanical filters 22, 24 and pre-filter 112 to the inlet 16. The pre-filter 112 provides a contact stabilization stratum, including the elements having active surfaces, prior to entry of the fluid into the active zone.

Additionally, the fluid is treated by a magnetic field as it is passing through the contact stabilization stratum. The fluid enters the accumulating passage 36 and then accelerates as it rises through the action zone along the membrane 50 between the vertical portions 60, 62 of electrodes 40, 42. In this action zone, the pH of the fluid is changed. Critically, the passage 36 and action zone act as a U-shaped connected vessel wherein the passage has a greater volume than the action zone so that the fluid naturally accelerates through the action zone.

5 The fluid is additionally power saturated by the fluid flowing over the top portion 68, 70 of the electrodes 40, 42 and about the current lead connectors interconnecting the electrodes 40, 42 to a power source. The fluid then flows over an edge 72, 74 of each electrode 40, 42, thereby 10 implementing an edge effect which stabilizes the pH change of each fluid flow. At least one of the electrodes 40 includes the extension 76 for providing an additional active power portion narrowly extending from the horizontal portion 68 of the electrode 40.

Preferably, there can be periodic pulse changing of the voltage and current parameters of the electrodes 40, 42 in the action zone. Also, the fluid flows between the electrodes 40, 42 in 15 the action zone in a direction opposite to the direction of electrical potential propagation along the electrodes. Further, a pulse current lead can be alternated with a stabilized current in the electrodes 40, 42 as the fluid flows therebetween, to further effectuate the effect of the system.

Aerosols and gases are removed to the filter assembly 87 containing the aluminosilicate granulated filter. These gases are guided to a cylindrical section of the filter assembly 87 in a 20 tangential direction, thereby producing a vortical effect. The fluid is then removed from the system through outlets 128, 130 as described below. Excess liquid can be emptied from the system through outlet 150, controlled by valve 152 (Fig. 7).

Various fluids can be treated in accordance with the present invention. For example, the

present invention can be utilized to adjust the pH of water treated by reverse osmosis, change the pH of waste water after various galvanic processes, change the pH of water before the water is applied to industrial washing processes, change water pH in the cooling towers of thermal power plants, boiler rooms, and other related systems, change the pH of liquids in various technological processes in pharmaceuticals, change the pH of liquids in various technological processes when producing cosmetics, change the pH of liquids in various technological processes when producing synthetic detergents, change the pH of liquids in various technological processes related to the food industry, change the pH of liquids in laboratories, demonstrate change in pH of liquids for training purposes in schools, and change the pH of water used in internal combustion engines. Thus, the present invention can be used in various systems demanding pH adjustment of liquids and solutions, in industrial and agriculture utilities.

In agriculture, the present invention enables the production of pH balanced water without the addition of chemicals. In a specific agricultural application, the control of pH is useful for insect control. In addition, inasmuch as a pH adjustment device as described herein will kill bacteria in the treated water, the pH adjustment process can be used in crop disinfection and the disinfection of udders of milk cows, as well as for washing produce. In industry, the present invention is useful for producing high-pH water to be used as an emulsifying agent in cleaning oil and grease from automobile parts and machinery. Other applications include the removal of dental plaque, the production of detergents, the production of citric or acetic acid, and the production of activated water, i.e., water with a high electro-potential. Activated water may be useful as a pre=treatment in many processes.

Membrane 50 may be omitted in some applications, for example, in a coagulation process to break up cyanides, undesired metallics and other toxic substances.

In sedimentation or flotation separation processes, overspill to another system pollutes the water. Using a pH adjustment device as described herein will not only produce sedimentation but will also impart an electropotential to the water, which facilitates ion exchange or reverse osmosis. Membranes do not clog as quickly and efficiency is increased.

5 A pH adjustment device as described herein may be used for producing an aqueous solution of a pH value which is predetermined to be optimal for the removal of different contaminants, for example, heavy metals and other toxins.

Water of a certain pH may be beneficial for skin treatment.

Another area of application is in the production of antistatic washes for airplanes, the  
10 textile industry, paper production, microelectronics, and the optical industry. In the electronics industry, the pH adjustment device may be connected to a differential flow surface (like an airplane wing) to which semiconductor plates or computer chips are attached for cleaning purposes.

The following is an example of the subject device and method in implementation. An  
15 acidity change (pH) was effected in water after its treatment in a device constructed in accordance with the present invention of reverse osmosis. Water parameters after the reverse osmosis installation were: pH 4 -5 , conductivity-30 micro-S, temperature 20°C. Influent water before treatment on the reverse osmosis device was common drinking water from water basins with general mineralization of 200 to 300 mg per liter and conductivity of about 400 micro-S,  
20 pH 7.5. The remaining parameters and concentrations were in compliance with drinking water standards. The operation schedule of the device used for the acidity change for this example were: consumption 250 liter per hour, voltage 52 V, current intensity 0.3 A, titanium electrodes having a width of 20 mm and a contact zone length of 300 mm. The distance between the

electrodes was 6 mm and distance between the electrodes and membranes was 2.8 mm. The membrane was neutral and made from polypropylene fabric. After passing the inter electrode space, the water parameters were pH 8.5, conductivity 29 micro-S, having a temperature of 21.5°C, and general mineralization of 25 mg per liter. Hence, there was an effective pH change 5 and significant demineralization of the water with very little temperature change. There was also a significant decrease in conductivity. Hence, the present invention has utility for changing the pH of various flowable aqueous fluids in various industries and agricultural situations.

As illustrated in Fig. 9, a system for the batch processing of a liquid to alter the pH thereof comprises an electrochemical or electrodialytic cell 154 which generally includes a pair 10 of electrodes spaced from one another by a distance of less than approximately 10 cm and provided with a membrane for dividing an interelectrode space into two subchambers or channels for laminar fluid flow. The fluid to be treated to a pH adjustment process in cell 154 is stored in bulk in a batch reservoir 156 and is moved from the reservoir to a feed tank 158 by a pump 160 at the commencement of batch treatment cycle. After the filling of tank 158 to a predetermined 15 level, a valve 162 is opened to enable delivery of the fluid from the tank through a flow meter or rotameter 164 to the cell 154. The rate of fluid flow into cell 154 is measured by the flow meter 164 and communicated to a power supply and controller unit 166. The power supply is switched on when the flow rate as measured by the flow meter 164 attains a pre-set magnitude. The power supply and controller unit 166 operates valve 162, as well as three valves 168, 170, 172 at 20 outputs of the electrochemical cell 154. The valves 168, 170 control the flow of acidic and basic solutions from the cell 154 to respective effluent containers 174, 176. The valves 168, 170 are connected to the valve 172 which in turn communicates with a mixing tank 178. Accordingly, appropriate activation of the valves 168, 170, 172 enables a controlled mixing of acidic and basic

effluents to produce a liquid having a desired intermediate pH value which is received in the mixing tank 178. The system of Fig. 9 may be converted into a continuous-type processing system by feeding a continuous stream of liquid to the electrochemical cell 154 via the flow meter 164 and a valve 180.

5 Fig. 10 depicts a modified continuous-type pH adjustment system. Fluid 182 from a reservoir 184 is conveyed along two paths 186, 188 by a pair of pumps 190, 192. The flow along the paths 186, 188 is regulated by respective valves 194, 196 and monitored by respective flow meters 198, 200. The paths 186, 188 have laminar path segments 202, 204 disposed between a membrane 206, on the one side, and the respective electrodes 208, 210, on the other side. The 10 electrodes 208, 210 are energized by respective power supplies 212, 214 which are connected to the electrodes by current lead connectors in form of rods 216, 218. These rods 216, 218 extend particularly to horizontally oriented extensions 220, 222 of the electrodes 208, 210.

The pH adjustment process carried out by the system of Fig. 10 is controlled by a microprocessor 224. The microprocessor 224 receives feedback from the flow meters 198, 200 15 as to the volume flow rate of the fluid along the paths 186, 188. In response to that flow rate information, the microprocessor energizes the pumps 190, 192 and activates the valves 194, 196 so that the pH levels of effluent at 226, 228 accord with a pH adjustment level programmed into the microprocessor 224 by an operator. Generally, the effluent streams 226 and 228 has a different pH, one acidic, i.e., an anolyte, and the other basic, i.e., a catholyte.

20 In order to fine tune the effluent pH, the microprocessor 224 causes a volume flow rate change along one or both paths 186, 188. In addition, the microprocessor 224 is connected to the power supplies 212, 214 for controlling the operation thereof. More specifically, the microprocessor 224 determines various parameters of the voltage output of the power supplies,

including the waveform shape, the frequency or periodicity thereof, the duration of pulses and the times between successive pulses, the amplitude, etc.

As illustrated in Fig. 11, another continuous-type pH adjustment system comprises an electrochemical or electrodialytic adjustment cell 230 having an I-shaped configuration with a pair of inlet ports 232, 234 and a pair of outlet ports 236, 238. Cell 230 contains a pair of electrodes 240, 242 each having a vertically oriented main portion 244, 246 and a horizontal extension 248, 250 at an upper end. Each horizontal extension 248, 250 is provided with a respective pH-stabilization edge 252, 254 disposed at a trailing end of the extension. A vertically oriented membrane 256 is disposed between the main electrode portions 244, 246 for defining a pair of flow path segments or action zone subchambers 258, 260 between the electrode portions 244, 246.

A pair of conduits 262, 264 extend to the inlet ports 232, 234 of the electrochemical or electrodialytic adjustment cell 230 from a fluid reservoir 266 which is provided with a mixer 268. Fluid is delivered from the reservoir 266 to inlet ports 232, 234 under the action of a pair of pumps 270, 272. The volume flow rates of the fluid through the conduits 262, 264 are monitored by two flow meters or rotameters 274, 276.

The outlet ports 236, 238 of the electrochemical or electrodialytic adjustment cell 230 are connected to a pair of conduits 278, 280 which extend to a receiving tank 279 provided with a stirrer 281. The receiving tank 279 is provided with an ancillary chamber 282 which is isolated by a partition 284 from turbulence caused by stirrer 281. A pH sensor or detector 286 inserted into ancillary chamber 282 is operatively connected to a controller 288 such as a microprocessor.

Sensor or detector 286 automatically measures a pH of a liquid stream emptying into receiving tank 279 of the electrochemical cell assembly. Controller or microprocessor 288

automatically compares the measured pH with a preselected reference pH value. This reference pH value may be input into the controller by a human operator. As discussed hereinafter, one or more flow rates through the device are adjusted in response to the results of the comparison of the measured pH with the preselected reference pH value.

- 5       The outlet ports 236, 238 of the electrochemical or electrodialytic adjustment cell 230 are connected to the respective inlet ports 232, 234 via feedbacks loops 290, 292 each incorporating a flow meter or rotameter 294, 296 and a valve 298, 300. The valves 298, 300 are operated by the controller 288, as are the pumps 270, 272. The controller 288 energizes the pumps 270, 272 and determines the state of the valves 298, 300 in response to the pH of the output fluid in the
- 10      tank 278 and in accordance with a desired pH level programmed by an operator. The rotameters 274, 276, 294, 296 are operatively connected to controller 288 for informing the controller of instantaneous volume flow rates. The controller 288 is optionally connected at an output to a dual power supply 302 for modifying voltages which are applied to electrodes 240, 242. As discussed above, the amplitudes, frequencies or periodicities, polarizations, waveforms or pulse
- 15      shapes (rectangular, sawtooth, etc.), and other characteristics of the voltages may be varied by controller 288.

In the pH adjustment system of Fig. 11, a desired pH may be produced in the receiving tank 279 by the microprocessor's operating of the valves 298, 300 to determine the proportional amounts of low pH and high pH fluids which are recycled or returned to the inlet ports 232, 234.

- 20      The microprocessor 288 may also vary the pumping speeds of the pumps 270, 272 to compensate for the return of fluid to the inlet ports 232, 234 via feedback loops 290, 292. The pH adjustment system of Fig. 11 allows lower or higher pH values to be reached, depending on which side is "looped back" to its respective inlet port 232, 234. Generally, to achieve pH values beyond the

first pass, looping or returning the flow to the head end of the reactor cell can be implemented.

The embodiments of Figs. 9, 10, and 11 may include a filter assembly 87 as described above with reference to Figs. 6A and 6B and/or a pre-treatment system 112 as described above with reference to Fig. 7. It is to be noted that in all of the embodiments of a pH-adjustment device as described herein except for Fig. 9, fluid flow is in an upward direction between main portions of the electrodes. Subsequently, the pH-adjusted fluid flows laterally outwardly over horizontal electrode extensions and past pH-stabilization edges. In the system of Fig. 9, flow could be in an upward flow direction through the electrochemical or electrodialytic cell 154.

The embodiments of Figs. 9, 10, and 11 may additionally include a heat exchanger upstream of the electrochemical or electrodialysis cell, for purposes of cooling the inflowing liquid to compensate for heating of the electrodes. Moreover, the electrodes may be movably mounted to the housing of the electrochemical cell, thereby enabling an adjustment in the distance between the electrodes and the distances between the electrodes and the membrane.

Tests were performed on tap water having the characteristics set forth in Table I. These tests were done using batch processing, as described hereinabove with reference to Fig. 9.

pH	7-7.4
Conductivity	400-460 µS
Total Alkalinity	80 - 86 mg/L as CaCO <sub>3</sub>
Total Hardness	140 - 150 mg/L as CaCO <sub>3</sub>
Ca hardness	95 - 105 mg/L as CaCO <sub>3</sub>
Cl <sup>-</sup>	90 - 95 mg/L as Cl <sup>-</sup>
Total residual Cl <sub>2</sub>	< 0.03 mg/L as Cl <sub>2</sub>

Table I

The results of those tests are listed in Table 2 and illustrated in the graphs of Figs. 12A-12D. The initial pH of the water was 7.29. The tests were run at three different flow rates, namely, 50 L/hr, 100 L/hr, and 150 L/hr. Figs. 12A and 12B show significant pH differences in both anolyte and catholyte, especially at low flow rates. For example, at a flow rate of 50 L/hr, 5 the differences in pH values between the input water and the acidic and basic product waters were found to be 4.49 and 3.48, respectively. Since pH values are log values of hydrogen ion concentration, passing tap water through an electrochemical pH adjustment system as described herein can result in an increase of 30,900 fold in the concentration of hydrogen ions in the anolyte effluent and a change of 3,020 fold in the hydroxyl ion concentration in the catholyte 10 effluent.

Flow Rate (L/hr)	Amperage (amps)	Voltage (volts)	Power (watts)		pH	Conductivity ( $\mu$ S)	pH Change
50	4.70	95.60	449.32	Acid Side	2.80	1260	4.42
				Base Side	10.77	536	3.55
100	3.57	98.00	349.86	Acid Side	3.58	545	3.64
				Base Side	10.07	447	2.85
150	3.22	99.00	318.78	Acid Side	6.05	413	1.17
				Base Side	9.78	438	2.56
				Influent	7.29	425	

Table II

As indicated in Table II and illustrated in the graphs of Figs. 12A-12D, lower flow rates resulted in an end product of higher conductivity but required more amperage and hence

consumed more power. Clearly, significant pH changes can take place at both the anode and cathode of an electrochemical or electrodialytic cell as described herein, even using tap water as the influent or source fluid.

Further tests were made using a variety of inorganic ions as represented by different 5 laboratory solutions comprising deionized water and chemically pure monovalent, divalent and trivalent cations and anions. The tests were conducted on different combinations and concentrations of the cations and anions. The ions tested, the concentrations and a summary of the laboratory results are tabulated in Table III.

Cation	Anion	Compound		Concentration (mg/L)	Conductivity ( $\mu$ S)	Power (watt)
Monovalent	Monovalent	NaCl	Acid Side	100	225	75.35
			Base Side	100	225	75.35
Divalent	Monovalent	CaCl <sub>2</sub>	Acid Side	60	130	61.9
			Base Side	60	130	61.9
Monovalent	Divalent	Na <sub>2</sub> SO <sub>4</sub>	Acid Side	60	134	42.14
			Base Side	80	134	42.14
Divalent	Divalent	CaSO <sub>4</sub>	Acid Side	200	320	65.94
			Base Side	200	320	65.94
Trivalent	Monovalent	AlCl <sub>3</sub>	Acid Side	100	295	133.39
			Base Side	100	295	133.39
Trivalent	Divalent	Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	Acid Side	500	694	590.82
			Base Side	500	694	590.82

Table III

The results listed in Table III are plotted in Figs. 13A-13F for pH, in Figs. 14A-14F for pH differences (between input and output pH values), in Figs. 15A-15F for conductivity, in Figs. 16A-16F for ion imputed activity, and for power consumed in Figs. 17A-17F.

As shown in Figs. 13A-13F and 14A-14F, significant pH changes occurred. Most of the 5 monovalent and divalent solutions tested showed increases in pH of up to 5 and even 6 pH units, after passage through an electrochemical or electrodialytic cell as described herein. The results more particularly indicate that increasing concentrations of the ions will not result in further changes in pH. All of the ionic solutions showed plateaus of pH values with increasing concentrations.

10 In generally, monovalent ions showed greater pH differences than divalent and trivalent ions which for the ion selected gave the least measurable pH changes. Aluminum chloride, a trivalent cation paired with a monovalent anion, did not show very great pH differences and alum ( $\text{Al}_2(\text{SO}_4)_3 \cdot 7\text{H}_2\text{O}$ ) gave only slightly better performance.

Excluding the trivalent ions, a larger pH differential was observed at the anode, the base 15 producing electrode. While the acid side of the reactor also gave significant pH changes of 3 pH units (1,000) fold, the results were generally lower than those measured at the basic side of the reactor.

All of the factors examined, namely, concentration, conductivity, ion activity, and power, exhibited a rise or decrease in pH followed by a plateau. More specifically, the results show that 20 once the concentration of salts reached levels above about 200 mg/L or showed conductivities of about 400 microohms, it is possible to obtain significant pH changes, especially with monovalent and divalent cations and anions, but noticeably less with trivalent cations. Increasing concentrations beyond a certain level for all of the ion species tested resulted in obvious plateaus.

As depicted in Fig. 17, another system for altering the pH of a liquid includes a reservoir or source 304 connected to a pump 306 via a conduit 308. The pump 306 moves liquid from the reservoir 304 through the conduit 308 and a pipe 310 to an inlet port 312 of an electrochemical or electrodialytic cell 314. The inlet port 312 communicates with an accumulating passageway 5 or channel 316 of the electrochemical or electrodialytic cell 314 which in turn communicates with an accelerating passageway or channel 318 via an aperture 320. Fluid introduced into the electrochemical or electrodialytic cell 314 through the inlet port 312 flows downwardly along the accumulating passageway 316, through the aperture 320 and upwardly along the accelerating passageway 318 between panels or partitions 322 and 324. At an upper end of the accelerating 10 passageway 318, on opposite sides thereof, are disposed an electrode 326 and a membrane 328 defining a sub-chamber 330 of an action zone 332.

After passing through the subchamber 330 of the action zone 332, fluid flows over a horizontal extension 334 of the electrode 326 and past a pH-stabilizing edge 336 at the trailing or downstream end of the horizontal electrode extension 334. The fluid exits the electrochemical or 15 electrodialytic cell 314 and is guided through a pipe 338 to a pump 340 which moves the fluid through a conduit 342 into a second accumulating passageway 344 of the electrochemical or electrodialytic cell 314. At a lower end, the second accumulating passageway 344 communicates with a lower end of a second accelerating passageway 346 via an aperture 348. The second accelerating passageway 346 is defined by the partition 324 and another partition 350. At an 20 upper end, the second accelerating passageway 346 is flanked by the membrane 328 and another electrode 352 which define another sub-chamber 354 of the action zone 330. Fluid moving upwardly through the accelerating 346 passageway passes through the sub-chamber 354 and then laterally over a horizontal extension 356 of the electrode 352 and past a pH-stabilizing edge 358

at the downstream end of the horizontal extension 356. Effluent exits the system via a pipe 360.

It is to be noted that the directions of fluid flow can be reversed. Thus, the system can be reconfigured so that the pump 306 conveys fluid from the reservoir 304 to the conduit 342 and thus to the upper end of the accumulating passageway 344, while the pump 340 moves fluid from 5 the pipe 360 downstream of the electrode 352 to the upper end of the accumulating passageway 316. The effect of this system reconfiguration can be alternatively achieved by reversing the polarity of the electrodes 326, 352. Those electrodes are supplied with d-c or a-c power from a source 362 which is connected to the horizontal extensions 334, 356 of the electrodes 326, 352 via current lead connector rods 364, 366.

10 It is to be noted that the system of Fig. 17 incorporates two U-shaped connected vessels. The first vessel includes accumulating passageway 316 as one leg and accelerating passageway 318 as the other leg. The second vessel includes accumulating passageway 344 and accelerating passageway 318 as the two legs. Also, pump 340 may be omitted so that the fluid is pressure fed.

15 An example of reversing the flow is indicated in Tables IV and V. The first flow direction was through the acid side and the second flow direction was through the base side. Reversing the flow pattern to the base side followed by the acid side shows a pH range of 6.55 to 7.29 and the highest pH was at the higher flow rate. It is well understood that the changing of variables could change the results. These could include variables such as electrode spacing, 20 membrane material, electrode material, electrode length, power input, and flow rate.

Influent	Pumped Back	pH	Conductivity	Temp.	Total Cl <sub>i</sub>	Amperage	Voltage	Watts
400	400	9.11	443	34.7	9.98	5.73	102.2	585.61
800	800	8.98	387	24.5	3.03	3.46	106.8	369.53
1200	1200	8.88	364	21.5	0.7	2.96	108.1	319.98

5

Table IV

Influent	Pumped back	pH	Conductivity	Temperature	Total Cl <sub>i</sub>	Amperage	Voltage	Watts
400	400	6.55	420	31.7	7.76	4.28	104.7	448.12
800	800	7.17	376	23.5	2.37	3.12	107.3	334.78
1200	1200	7.29	367	21.6	1.35	2.89	107.6	310.96

10

Table V

In the particular electrochemical cell 314 used to generate the results of Tables IV and V, the electrodes 326, 352 (not including the horizontal extensions 336, 356) were approximately 10 and 11/16 inches long and 1/16 inch thick. The distance between the electrodes 326, 352 was approximately 1/4 inch, while the distance between each electrode 326, 352 and the membrane 15 328 was approximately 3/32 inch. The membrane 328 and a holder or frame (not separately illustrated) therefor had a length or height of approximately 12 1/2 inches. The distance between each partition 322, 350 and partition 324, i.e., the width of accelerating passageways 318, 346, was approximately 3/16 inch, whereas the width of each accumulating passageway 316, 344 was approximately 2.75 inches. The reduction in cross-sectional area (assuming the same breadth) 20 from the accumulating passageways 316, 344 to the respective accelerating passageways 318, 346 is representative of other embodiments of a pH adjustment apparatus disclosed herein.

When tap water is first passed through the acid side of the series flow system of Fig. 17, a

sterile water is produced. This has been demonstrated in laboratory tests described below. The passage of water through the acid side would also wash out non-sterile water present in the basic side of the series flow system. This assures the input of low pH, chlorine contacted water with a disinfection capability so that the basic side would be displaced by a sterile water as a final product.

The ability of the electrochemical or electrodialytic of Fig. 17 to produce water on demand with almost instant sterilizing properties makes available to the user a means of providing a safe sterilizing rinse water that possesses topical disinfection qualities capable of killing most pathogenic microorganisms that are a public health concern. Applications include a personal hand sanitizing rinse water for individuals handling food, a disinfecting rinse water for providing a sanitizing rinse for meats, poultry, vegetables or fruit as well as for cooking utensils or sick room supplies. In such applications, a primary disinfecting rinse for a short period would also be of use in industries where sterile water is required for washing, rinsing or in producing a product. Examples of such applications are in the food and beverage industry and in the cosmetics industry.

If the liquid is passed through the basic side first, it would not produce sterile water. However, passage of the base side effluent through the acid side will produce chlorine at a pH near or above neutrality. The water would be partially disinfected but would not provide the advantages of the acid first water described above.

As illustrated in Figs. 18 and 19, an electrochemical or electrodialytic cell for generating a pH change in a liquid comprises a container or casing 368 having a first pair of inlet ports 370, 372 which are connectable to a source of liquid (not illustrated) and which lead to respective accumulating passageways, channels or chambers 374, 376. At their lower ends, these

passageways 374, 376 contain metal-coated ceramic bodies 378, 380, 382, 384 disposed in contact with an incoming water stream 386 for preventing or inhibiting plating on the surfaces and edges of a pair of electrodes 388, 390. The electrodes 388, 390 define an action zone or chamber 392, which is subdivided into two sub-chambers 394, 396 by a membrane 398. After flowing around metal-coated ceramic bodies 378, 380, 382, 384, the fluid passes through apertures 400, 402 in electrically insulating internal panels 404, 406 of the electrochemical or electrodialytic cell to enter the sub-chambers 394, 396 of the action zone 392. The electrodes 388, 390 are each provided at an upper end with a horizontal extension 412, 414 connected to a power supply 415 via a respective current lead connector rod 416, 418.

Ion exchange occurring in the action zone 392 during the flow of liquid vertically upwardly through the sub-chambers 394, 396 is symbolized in Fig. 19 by criss-crossing arrows 420, 422. The liquid exits sub-chambers 394, 396 via aligned perforations 424, 428 disposed in the electrodes 388, 390 and the internal panels 404, 406 and enters the upper ends of a pair of exit chambers 430, 432.

In one mode of operation of the electrochemical or electrodialytic cell of Figs. 18 and 19, the pH-adjusted and -stabilized liquid flows downwardly through the exit chambers 430, 432 and passes out of the cell through outlet pipes 434, 436, as indicated by arrows 438, 440.

In an alternate mode of operation of the electrochemical or electrodialytic cell of Figs. 18 and 19, the pH-adjusted and -stabilized liquid is prevented from exiting the cell via one of the outlet pipes 434 or 436, for example, by the closure of a valve (not shown) connected to the respective outlet pipe. Instead, the liquid leaves the respective exit chamber 430 or 432 via an outlet tube 442 or 444 and is fed over an external conduit 446 or 448 to an auxiliary inlet port 450 or 452 connected to the upper end of the opposite accumulating passageway or chamber 374,

376. This mode of operation is described hereinabove with reference to Fig. 17.

Figs. 20 and 21 depict a modification of the electrochemical or electrodialytic cell of Figs. 18 and 19. The structural elements in Figs. 20 and 21 which are identical to corresponding elements in Figs. 18 and 19 bear the same reference designations as in Figs. 18 and 19. As illustrated in Figs. 20 and 21, a pair of opposed electrodes 454, 456 are each formed in an upper region with a plurality of recesses 458 having peripheral edges 460 which perform the pH stabilization function described hereinabove. The recesses 458 are located along parabolic arcs 462 which open upwardly as shown. Additional recesses 464 may be provided in lower regions of the electrodes 454, 456.

10 As depicted in Figs. 20 and 22, the recesses 458 (and 464) have a flat base 466.

Alternatively or additionally, the electrodes 454, 456 may be provided with perforations 468 as shown in Fig. 23 or recesses 470 having a conical base or bottom 472, as shown in Fig. 24.

Fig. 25 depicts another electrochemical or electrodialytic cell for adjusting the pH of a fluid and ensuring that the pH change is stable. The electrochemical or electrodialytic cell of 15 Fig. 25 is a modified version of the electrochemical or electrodialytic cell of Figs. 18 and 19. The structural elements in Fig. 25 which are identical to corresponding elements in Figs. 18 and 19 bear the same reference designations as in Figs. 18 and 19.

As illustrated in Fig. 25, a pair of electrodes 474, 476 face one another and define a pH-adjustment action zone or chamber 478. The action zone 478 is divided into two sub-chambers 20 480, 482 each of which is flanked by the membrane and a respective one of the electrodes 474, 476. As depicted in Figs. 25 and 26, the upper portions of the electrodes 474, 476 are each provided along their inwardly facing surfaces with a plurality of projections 484 which extend into the respective sub-chamber 480, 482. The projections 484 are arranged along upwardly

opening parabolic arcs 486. As shown in Fig. 27, each projection 484 includes a head portion 488 and a shaft portion 490. The head portion 488 is disposed in the respective sub-chamber 480, 482, while the shaft portion 490 is seated in a recess or perforation 492 provided in the respective electrode 474, 476. In the case of a recess, the bottom surface of the recess may be 5 planar, conical, hemispherical, etc. The head portion 488 of the projection 484 has a circular edge 494 on an inwardly facing side (facing the other electrode) which serves to perform the pH stabilizing function described hereinabove. To that end, the projections 484 are generally made of the same electrically conductive and electron-scavenging material as the electrodes 474, 476.

As illustrated in Fig. 27, the head portions 488 of the projections 484 may be flat. 10 Alternatively, as shown in Fig. 28 and 29, one or both of the electrodes 474, 476 may be provided with projections 496 or 498 having an inwardly conical or concave head portion 500 or an outwardly conical or convex head portion 502. The inwardly conical or concave head portion 500 has a pH-stabilizing edge 504, while the outwardly conical or convex head portion 502 has a pH-stabilizing edge 506.

15 Generally, the projections 484, 496, 498 on one of the electrodes 474, 476 are aligned or registered with the projections 484, 496, 498 on the other electrode 476, 474. Where one of the electrodes 474, 476 is provided with projections 498 having the outwardly conical or convex head portion 502, the other electrode 476, 474 is preferably, but not necessarily, provided with projections 496 having the inwardly conical or concave head portion 500.

20 It is to be noted that the electrodes of an electrochemical or electrodialytic cell as described herein may be provided with various combinations of recesses and projections. Thus, one electrode may have all recesses while the other electrode is provide solely with projections. Alternatively, one or both electrodes may be provided with both recesses and projections.

Turbulence may be introduced into the fluid flow through the action zone of an electrochemical or electrodialytic cell for purposes of ensuring a more uniform, reliable and efficacious pH change. For example, as illustrated in Fig. 25, teeth 508, 510 are provided at the inlet end of the action zone 478 and particularly at the downstream ends of apertures 400, 402, 5 where those apertures communicate with the sub-chambers 480, 482 of the action zone 478. Similar turbulence-inducing teeth 512, 514 are disposed at the outlet ends of sub-chambers 480, 482 where those sub-chambers are connected with apertures 424, 426.

One of the applications of an electrochemical or electrodialytic process as described herein is for disinfection. The electrochemical or electrodialytic cell can be used to produce a 10 low level solution of chlorine suitable for disinfection purposes. The chlorine can be produced from water containing low levels of chloride at concentrations presently found in most naturally occurring water and wastewater.

About 100,000 fecal coliform bacteria per mL was added to New York City tap water and passed through an electrochemical or electrodialytic cell as described hereinabove. The process 15 resulted in an instant kill of 100% at the low chlorine levels used (1.6 mg/L) and the low pH (2.65) generated by the process. Additional testing on New York City tap water passed through the electrochemical or electrodialytic cell resulted in a 100% kill in thirty minutes.

Northvale, New Jersey, tap water that was processed using an electrochemical or electrodialytic cell as described above was found to be more lethal to fecal coliform bacteria than 20 water that was not processed by the electrochemical or electrodialytic cell and also had no chlorine as well as the same pH value of 2. Twenty minutes after the passage of the water through the electrochemical or electrodialytic cell and dechlorination, fecal coliform levels were reduced to zero from an initial concentration of about 600, 000 fecal coliform bacteria per mL,

whereas comparable water of pH 2 that was not passed through the cell and had no chlorine resulted in a value of 2800 fecal coliform bacteria per mL. This data strongly suggests that the electrochemical or electrodialytic cell imparts something to the water other than low H and no chlorine that resulted in greater lethality to fecal coliform bacteria.

5       The present invention enables the production of a target pH from incoming fluid of a different pH. In most applications requiring an aqueous solution of a particular pH value for industrial or agricultural use, the initial liquid generally has a pH in a range of 4.5 to 9 or 10. This is the pH range of potable water. The target pH may be anywhere from approximately 2 to approximately 13. The higher pH values have proven easier to attain than the lower pH values.

10       In waste water treatment applications, waste water may occasionally have a very low pH, for example, approximately 2.0 to 2.5 (or even a very high pH). In such cases, an electrochemical or electrodialytic cell assembly as disclosed hereinabove may be used to generate a water solution having a pH in the range of potable water, i.e., from about 4.5 to about 9 or 10.

15       Although the invention has been described in terms of particular embodiments and applications, one of ordinary skill in the art, in light of this teaching, can generate additional embodiments and modifications without departing from the spirit of or exceeding the scope of the claimed invention. For example, the electrodes of a pH adjustment device as described herein may be parallel or inclined towards one another so that the widths of the high-pH and  
20 high-pH flow channels decrease downstream. In addition, the electrodes might have a shape other than planar. For example, the electrodes and the membrane might all be cylindrical and generally coaxially disposed. In this case, the accumulating chamber may surround the action zone or chamber so that the U-shaped connected vessel is coaxially formed.

Where a membrane is provided, the membrane is generally disposed equidistant from and parallel to the two electrodes and midway therebetween. However, it is contemplated that the membrane may be disposed at an angle relative to the two electrodes.

The membrane, if provided, is generally electrically neutral. However, it is possible to  
5 place a positive or negative charge on the membrane.

Also, it is to be noted that in some applications, only a single electrode may be required. In such an embodiment, there may be only a single flow channel, which is alongside and in contact with the electrode. Where a second flow channel or passageway is provided, it is located on a side of the first channel opposite the electrode. A membrane may in that case separate the  
10 two flow channels or passageways. In any case and in all embodiments of an electrochemical pH adjustment apparatus or system disclosed herein, it is preferred to have the liquid flowing upwardly, against the action of gravity, in the action zone along the electrode(s). This direction of fluid flow in the action zone works to effectuate separation of precipitates, so that the precipitates are less likely to be entrained by the fluid. Preferably, although not necessarily, the  
15 liquid being subjected to electrochemical action flows past an electrode edge so as to stabilize the adjusted pH level.

Accordingly, it is to be understood that the drawings and descriptions herein are proffered by way of example to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

## CLAIMS:

1. A process for adjusting the pH of aqueous flowable fluid, comprising:  
electrochemically adjusting the pH of an aqueous flowable fluid; and  
electrochemically stabilizing the adjusted pH of the fluid.
2. The process defined in claim 1 wherein said stabilizing step is further defined as  
guiding the fluid having the adjusted pH over an edge of an electrode.
3. The process defined in claim 2 wherein said guiding step is further defined as guiding  
the fluid over an electrode of increased length to intensify the stabilizing of the pH of the fluid.
4. The process defined in claim 3 wherein said step of electrochemically adjusting the pH  
is further defined as introducing the fluid into a chamber separated into two sub-chambers by a  
permeable membrane, each sub-chamber being defined in part by a respective electrode, one of  
the electrodes being an anode and the other being a cathode.
5. The process defined in claim 4 wherein the introducing of the fluid into the chamber is  
further defined as moving the fluid along a working surface of each electrode and conveying  
positive and negative electrical potential into the fluid.
6. The process defined in claim 5, further including the steps of guiding the fluid into an  
inlet accumulating passage below the chamber, the passage having a greater volume than the  
chamber, and pumping the fluid from the passage up into the chamber and accelerating the fluid

flow through the chamber.

7. The process defined in claim 6 wherein said pumping step is further defined as supplying the fluid to the chamber via a channel which together with the chamber forms a U-shaped connected vessel in which a volume of the fluid is divided into the two sub-chambers.

8. The process defined in claim 4, further including the step of additionally power saturating the fluid flow.

9. The process defined in claim 8 wherein said power saturating step is further defined as guiding the fluid over a top portion of each of the electrodes and about a current lead connector interconnecting the electrodes to a power source.

10. The process defined in claim 9 wherein said step of guiding the fluid over a top portion of each electrode is further defined as contacting the fluid flow with the current lead connector as the fluid flows over a horizontal top portion of each electrode.

11. The process defined in claim 4 wherein said step of guiding the fluid over an electrode of increased length is further defined as guiding the fluid in one sub-chamber over one of the electrodes having an edge at a periphery of a top horizontal portion thereof and directing the fluid in the other sub-chamber over an electrode including an additional active portion downwardly extending from the horizontal portion thereof.

12. The process defined in claim 11 further including the step of retrieving the fluid from the chamber into vertically extending outlet channels, said additional active portion extending into a respective one of the outlet channels.

13. The process defined in claim 11 wherein a bottom portion of the additional active portion is inwardly bent, said fluid being constrained to flow over an edge of said horizontal portion and then to contact the edge of the additional active portion.

14. The process defined in claim 13 including the further step of further changing the fluid pH by exposing the fluid to a portion of the current lead having an additional active portion which is charged with positive or negative potential.

15. The process defined in claim 4 including the further step of removing gases from the chamber in a direction perpendicular to the direction of fluid flow in the chamber.

16. The process defined in claim 15 wherein said removing step is further defined by guiding compressed fluid to ejectors located opposite to one another on both sides of an upper part of the chamber.

17. The process defined in claim 16 further including the step of conveying the removed gases to a filter containing aluminosilicate granulated filler.

18. The process defined in claim 17 further including the step of guiding the removed

gases to a cylindrical section of the filter in a tangential direction and producing a vortical effect.

19. The process defined in claim 4 further including the step of supplying a direct current to the electrodes.

20. The process defined in claim 19 further including the step of periodically changing the voltage and current parameters of the electrodes in the chamber.

21. The process defined in claim 4 further including the step of passing the fluid through a contact-stabilization stratum including elements having active surfaces prior to the fluid entering the chamber.

22. The process defined in claim 21 wherein said passing step is further defined as contacting the fluid with spherical ceramic parts coated with metals possessing an increased electrode potential.

23. The process defined in claim 22 further including the step of treating the fluid by a magnetic field as it passes through the contact-stabilization stratum.

24. The process defined in claim 4 further including the step supplying the fluid to space between the electrode in the chamber direction opposite to the direction of electrical potential propagation along the electrodes.

25. The process defined in claim 24 further including the step of alternating a pulse current lead with a stabilized current in the electrodes as the fluid flows therebetween.

26. The process defined in claim 4 further including the step of neutralizing the membrane between the electrodes.

27. A process for treating an aqueous flowable fluid, comprising:  
supplying a fluid through a channel having the appearance and properties of a U-shaped connected vessel; and  
dividing the fluid into two branches including an inlet accumulating passage leading to an action zone between two electrodes wherein the action zone has a smaller volume relative to the inlet accumulating passage and accelerating the fluid flow from the inlet accumulating passage through the action zone complying with the physics of connected vessels.

28. A device for adjusting the pH of an aqueous flowable fluid, said device comprising:  
electrochemical adjusting means for adjusting the pH of the fluid; and  
electrochemical stabilizing means for electrochemically stabilizing the adjusted pH of the fluid.

29. The device defined in claim 28 wherein said device includes a chamber separated into two sub-chambers by a permeable membrane extending therebetween, each sub-chamber being defined in part by a respective electrode together defining a pH action zone therebetween, said electrochemical adjusting means comprising a portion of said electrodes disposed within said

action zone, each of said electrodes including a peripheral edge defining said stabilizing means over which fluid flow after passing through said action zone.

30. The device defined in claim 29 wherein said edges are shaped for ensuring hydrodynamic contact of all of the fluid with said edges as liquid flows off of said electrodes.

31. The device defined in claim 30 wherein each electrode includes a first vertically extending portion within said active zone and a second substantially horizontal portion extending from a top portion of said vertical portion, said horizontal portions extending in opposite directions from one another.

32. The device defined in claim 31 wherein at least one of said electrodes includes a substantially downwardly extending additional portion further stabilizing said pH adjustment.

33. The device defined in claim 32 wherein said additional portion is curved inwardly toward said first vertically extending portion.

34. The device defined in claim 29, further comprising additional power saturation means for additionally power saturating the fluid flow.

35. The device defined in claim 34 wherein said additional power saturating means includes a connect lead connector interconnecting each of the electrodes to a power source.

36. The device defined in claim 35 wherein said connectors are stream-lined relative to the fluid flow and are non-insulated and made of the same material as said electrodes.

37. The device defined in claim 29 wherein said electrodes are each formed with at least one recess defining

38. The device defined in claim 29 wherein each of said electrodes includes a working surface parallel to the working surface of other electrode, said membrane being disposed symmetrically with respect to said working surfaces.

39. The device defined in claim 29, further comprising an inlet accumulating passage below and in fluid communication with said chamber, said passage having a larger volume relative to a volume of said chamber so that fluid flow from said passage into said chamber accelerates the fluid as the fluid rises through said action zone.

40. The device defined in claim 29 wherein said electrodes are spaced 4 to 6 mm apart through said active zone, said membrane extending therebetween within said space.

41. The device defined in claim 29 wherein each electrode includes a peripheral portion having a fold therein angled 30° to 45° relative to said working surface of said respective electrode.

42. The device defined in claim 28 wherein said electrochemical adjusting means device

includes a pair of electrodes defining therebetween an action zone, each of said electrodes including an edge defining said stabilizing means over which fluid flow after passing through said action zone, each of said electrodes being provided with at least one recess defining the respective edge.

43. The device defined in claim 42 wherein each of said electrodes is provided with a plurality of pH-stabilizing recesses downstream of said action zone.

44. The device defined in claim 28 wherein said electrochemical adjusting means device includes a pair of electrodes defining therebetween an action zone, each of said electrodes including an edge defining said stabilizing means over which fluid flow after passing through said action zone, each of said electrodes being provided with at least one projection defining the respective edge and extending into a fluid flow path between said electrodes.

45. The device defined in claim 44 wherein the projections each have an apex with a shape taken from the group consisting of flat, inwardly conical, and outwardly conical.

46. The device defined in claim 28 wherein said electrochemical adjusting means device includes electrodes disposed within said action zone, said action zone having an inlet and an outlet, at least one of said inlet and said outlet being provided with an element for introducing turbulence into flow of fluid through said action zone.

47. The device defined in claim 28 wherein said element for introducing turbulence into

flow of fluid through said action zone is tooth shaped.

48. A device for treating a flowable fluid, said device comprising:
- an inlet;
  - a first passageway or chamber having a first cross-sectional flow area, said first passageway or chamber being connected to said inlet;
  - a second passageway or chamber connected at a first point to said first passageway or chamber and having a second cross-sectional flow area smaller than said first cross-sectional flow area, whereby fluid flowing from said inlet through said first passageway or chamber to said second passageway or chamber acquires a flow velocity in said second passageway or chamber which is greater than a flow velocity of said fluid in said first passageway or chamber;
  - an outlet connected to said second passageway or chamber at a second point higher than said first point, whereby fluid flow in said second passageway or chamber has a substantial component directed vertically upward; and
  - at least one electrode disposed in said second passageway or chamber.

49. A device for treating flowable fluids, comprising:
- panels defining therebetween a flow path;
  - at least one electrode disposed along said flow path, said electrode being provided with a formation taken from the group consisting of a recess and a projection; and
  - an electrically conductive connector operatively connected to said electrode for enabling generation of an electrical potential on said electrode to electrochemically adjust the pH of a solution flowing along said path past said electrode.

50. A method for disinfecting a liquid, comprising:
- providing an electrochemical cell having a pair of electrodes disposed adjacent to one another to define therebetween an action zone and additionally having an ion-permeable membrane disposed in said action zone between said electrodes for dividing said action zone into two passageways or chambers;
- feeding a solution to an inlet of first one of said passageways or chambers;
- guiding the solution from an outlet of said first one of said passageways or chambers to an inlet of a second one of said passageways or chambers; and
- generating a potential difference across said electrodes during feeding of said solution to said first one of said passageways or chambers and during the guiding of the solution from said outlet to the inlet of said second one of said passageways or chambers.

51. A liquid processing method comprising:
- providing an electrochemical cell assembly having at least one electrode disposed along an action zone;
- guiding a liquid stream through said action zone, said liquid stream having an initial pH value;
- during the guiding of said liquid stream, supplying a voltage potential to said electrode; and
- coordinating the guiding of said liquid stream and the supplying of said voltage potential to said electrode so that an effluent liquid stream at an outlet of said electrochemical cell assembly has a desired pH value different from said initial pH value.

52. The method defined in claim 51 wherein the coordinating step includes varying a flow rate of said liquid stream.

53. The method defined in claim 52 wherein the varying of said flow rate includes diverting at least a portion of said liquid stream from a downstream end of said action zone to an inlet end of said action zone.

54. The method defined in claim 53 wherein the varying of said flow rate further includes operating a pump to move said portion from said downstream end of said action zone to said inlet end.

55. The method defined in claim 52 wherein the varying of said flow rate includes operating a pump.

56. The method defined in claim 52, further comprising:  
automatically measuring a pH of a liquid stream at an outlet end of said electrochemical cell assembly; and  
automatically comparing the measured pH to a preselected reference pH value,  
the varying of said flow rate being implemented in response to the comparing of said measured pH to said preselected reference pH value.

57. The method defined in claim 52 wherein said liquid stream is a first liquid stream, also comprising directing a second liquid stream through said action zone, said action zone

having a first passageway or chamber and a second passageway or chamber, said first liquid stream being guided through said first passageway or chamber and said second liquid stream being directed through said second passageway or chamber, said first liquid stream and said second liquid stream being both derived at least in part from a third liquid stream, further comprising dividing said third liquid stream to form at least portions of said first liquid stream and said second liquid stream.

58. The method defined in claim 51 wherein said liquid stream is a first liquid stream, also comprising directing a second liquid stream through said action zone, said action zone having a first passageway or chamber and a second passageway or chamber, said first liquid stream being guided through said first passageway or chamber and said second liquid stream being directed through said second passageway or chamber, further comprising dividing an inlet liquid stream into said first liquid stream and said second liquid stream upstream of said action zone, said first liquid stream and said second liquid stream both having said initial pH value.

59. The method defined in claim 51 wherein said liquid stream is a first liquid stream, also comprising directing a second liquid stream through said action zone, said action zone having a first passageway or chamber and a second passageway or chamber, said first liquid stream being guided through said first passageway or chamber and said second liquid stream being directed through said second passageway or chamber, wherein said first liquid stream and said second liquid stream are along the same flow path through said electrochemical cell assembly, said second liquid stream being downstream of said first liquid stream.

60. The method defined in claim 51, further comprising stabilizing a pH level of said liquid stream at an outlet end of said action zone, said stabilizing including guiding said liquid stream so that a substantial amount of said liquid stream flows over an electrode edge after pH adjustment of said liquid stream in action zone, said edge being at a common electrical potential with said electrode.

61. The method defined in claim 51, further comprising feeding an incoming stream of liquid to an accumulating chamber upstream of said action zone, said accumulating chamber having a substantially greater volume than said action zone.

62. The method defined in claim 51, including the further step of removing gases from the electrochemical cell assembly.

63. The method defined in claim 51 wherein the coordinating step includes varying a characteristic of electrical power applied to said electrodes.

64. The method defined in claim 51 wherein said liquid stream is a first liquid stream, also comprising directing a second liquid stream through said action zone, said action zone having a first passageway or chamber and a second passageway or chamber, said first liquid stream being guided through said first passageway or chamber and said second liquid stream being directed through said second passageway or chamber, the coordinating step including controlling the directing of said second liquid stream.

60

65. The method defined in claim 51 wherein the guiding of said liquid stream includes directing said liquid stream in an at least partially upward direction along said electrode.

66. A liquid processing apparatus comprising:  
an electrochemical cell assembly having at least one electrode disposed adjacent to an action zone;

a flow guide extending to an inlet end of said action zone for delivering to said action zone a liquid stream having an initial pH value;

a voltage source operatively connected to said electrode to supply a voltage potential to said electrode; and

a flow control component operatively connected to at least one of said electrochemical cell assembly and said flow guide for coordinating said liquid stream and said voltage potential so that an effluent liquid stream at an outlet of said electrochemical cell assembly has a desired pH value different from said initial pH value.

67. The apparatus defined in claim 66 wherein said flow control component includes a flow rate control element for varying a flow rate of said liquid stream.

68. The apparatus defined in claim 67 wherein said flow rate control element includes a valve for selectively diverting at least a portion of said liquid stream from a downstream end of said action zone to an inlet end of said action zone.

69. The apparatus defined in claim 68, further comprising a pump for moving said

portion from said downstream end of said action zone to said inlet end.

70. The apparatus defined in claim 67 wherein said flow rate control element includes a pump.

71. The apparatus defined in claim 67, further comprising a pH detector disposed at an outlet end of said electrochemical cell assembly for automatically measuring a pH value of a liquid stream at said outlet end, said flow rate control element being operatively connected to said pH detector for varying said flow rate in response to a pH value measured by said pH detector.

72. The apparatus defined in claim 67, further comprising means for dividing an incoming liquid stream to form at least portions of said liquid stream and an additional liquid stream.

73. The apparatus defined in claim 66, further comprising channels connected to said electrochemical cell assembly dividing an inlet liquid stream into said liquid stream and an additional liquid stream upstream of said action zone, the streams both having said initial pH value.

74. The apparatus defined in claim 66 wherein said liquid stream is a first liquid stream, further comprising an additional flow guide extending to an inlet end of said action zone for delivering to said action zone a second liquid stream, said first liquid stream and said second

liquid stream being along a single flow path through said electrochemical cell assembly, said second liquid stream being downstream of said first liquid stream.

75. The apparatus defined in claim 74 wherein said electrode is made of a carbon composite which acts as an oxygen scavenger.

76. The apparatus defined in claim 66, further comprising means for stabilizing a pH level of said liquid stream at an outlet end of said action zone, said means for stabilizing including an electrode edge of said electrode.

77. The apparatus defined in claim 66, further comprising an accumulating chamber upstream of said action zone and in fluid communication therewith, said accumulating chamber having a greater volume than said action zone.

78. The apparatus defined in claim 66, further comprising means operatively connected to said electrochemical cell assembly for removing gases from said electrochemical cell assembly.

79. The apparatus defined in claim 66 wherein the flow control component includes means for varying a flow of electrical power to said electrode.

80. The apparatus defined in claim 66 wherein said flow guide and said action zone are configured to direct said liquid stream in at least a partially upward direction along said electrode.

81. A device for treating a flowable fluid, comprising:
- an electrode disposed adjacent to a flow path;
- an electrically conductive connector operatively coupled to said electrode for enabling supplying of a voltage potential to said electrode to electrochemically adjust the pH of a solution flowing along said path in contact with said electrode; and
- flow guide conduits or passageways defining said flow path so that said solution flows in an at least partially upward direction along said electrode.
82. The device defined in claim 81, further comprising an additional flow guide directing said solution along said path so that a substantial amount of said solution flows over an electrically conductive edge after pH adjustment of said solution, said edge being at a common electrical potential with said electrode.
83. The device defined in claim 82, further comprising a flow control assembly for controlling a volume flow rate of said solution along said path.
84. The device defined in claim 83 wherein said flow control assembly includes a pH detector disposed downstream of said electrode.
85. The device defined in claim 84 wherein said electrode is one of two electrodes disposed on opposite sides of an action zone along said flow path, further comprising a membrane disposed between said electrodes to partition said flow path into two separate flow zones.

86. The device defined in claim 85 wherein said flow control assembly includes a first element for adjusting a volume flow rate through one of said flow zones and a second element for adjusting a volume flow rate through another of said flow zones.

87. The device defined in claim 86 wherein said first element and said second element of said flow control assembly are respective pumps.

88. The device defined in claim 87 wherein said one of said flow zones has an input end and an output end, further comprising:

at least one flow channel extending back from said output end to said input end; and  
a flow rate adjuster along said flow channel for varying a volume flow rate of pH adjusted liquid along said channel from said output end to said input end.

89. The device defined in claim 87 wherein said flow control assembly is operatively connected to said flow rate adjuster for determining the operation thereof.

90. A device for treating a flowable fluid, comprising:  
a pair of electrodes disposed adjacent to one another to define therebetween an action zone;

an ion-permeable membrane disposed in said action zone between said electrodes for dividing said action zone into two passageways or chambers;

a first pair of channels connected to said passageways or chambers to deliver separate streams of fluid to said passageways or chambers; and

electrically conductive connectors operatively connected to said electrodes for enabling generation of a potential difference across said electrodes to electrochemically work on a solution flowing along a path extending through said action zone between said electrodes.

91. The device defined in claim 90, further comprising a flow control element disposed along said path for adjusting a volume flow rate through one of said passageways or chambers.

92. The device defined in claim 91, further comprising a pH detector disposed downstream of said electrodes, said pH detector being operatively connected to said flow control element.

93. The device defined in claim 90 wherein said one of said passageways or chambers has an input end and an output end, further comprising:

at least one flow channel extending back from said output end to said input end; and  
a flow rate adjuster along said flow channel for varying a volume flow rate of pH adjusted liquid along said flow channel from said output end to said input end.

94. The device defined in claim 90 wherein said one of said passageways or chambers has an input end and the other of said passageways or chambers has an output end, further comprising at least one flow channel extending back from said output end to said input end.

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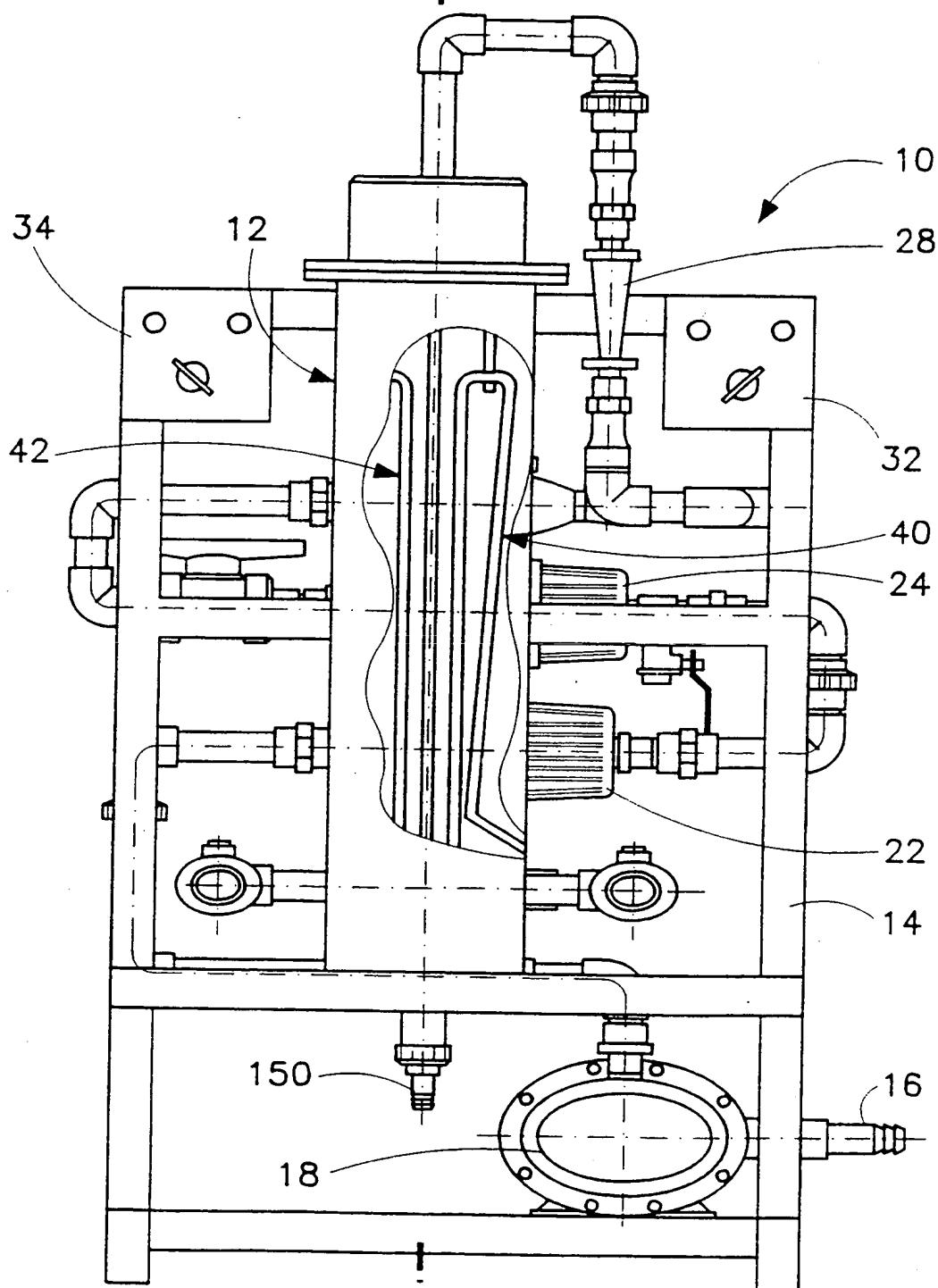


FIG. 1

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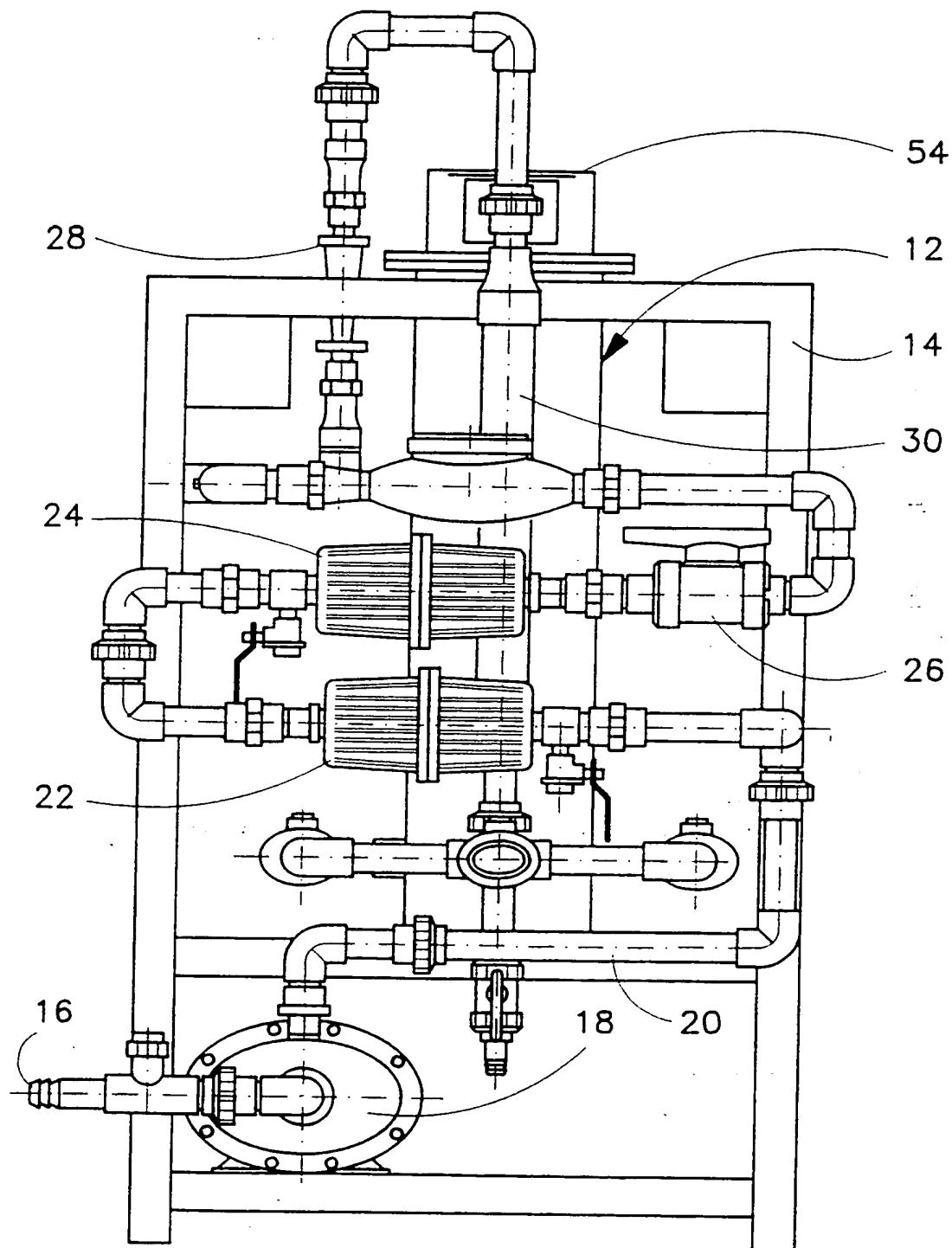


FIG. 2

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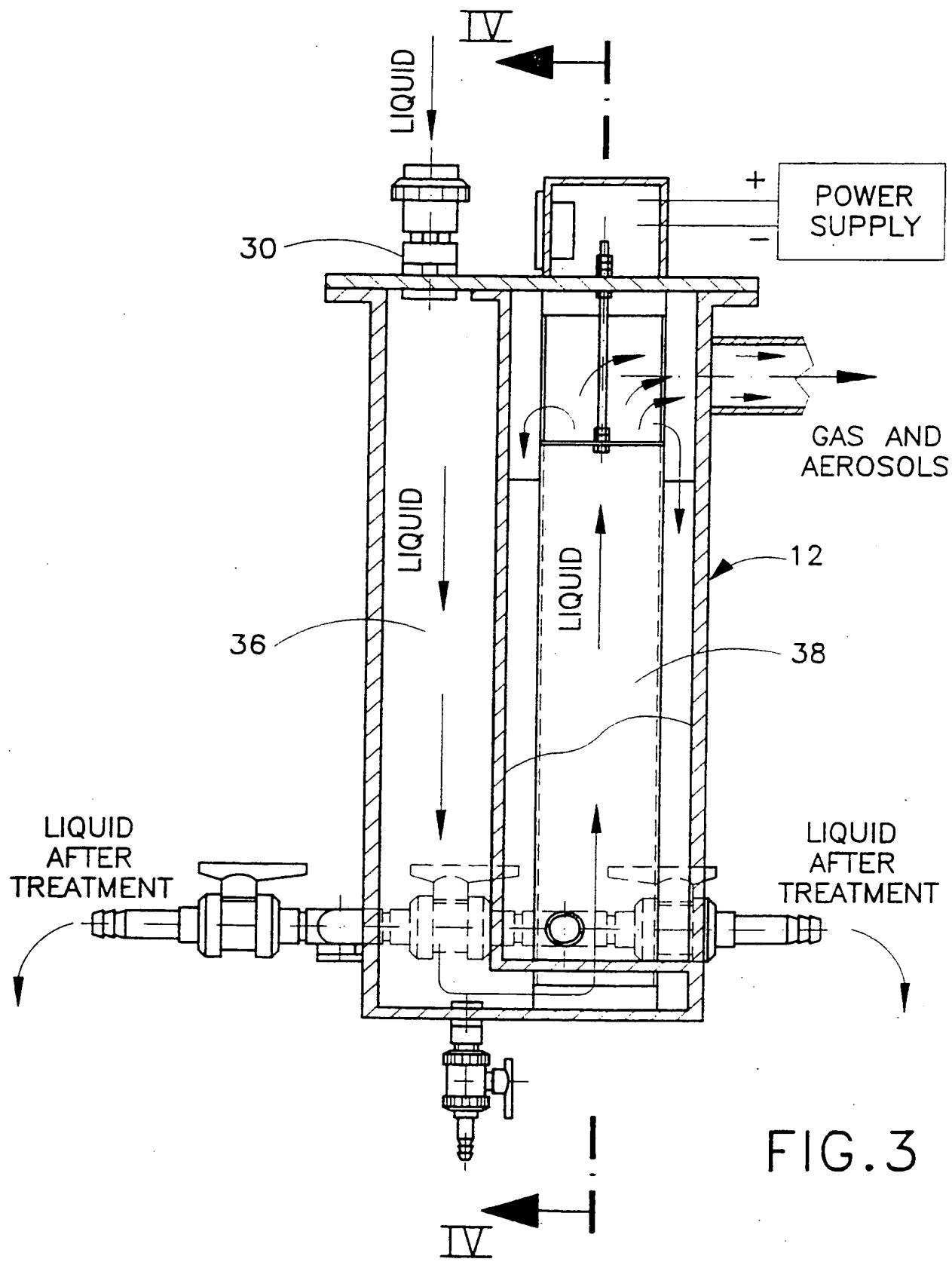


FIG. 3

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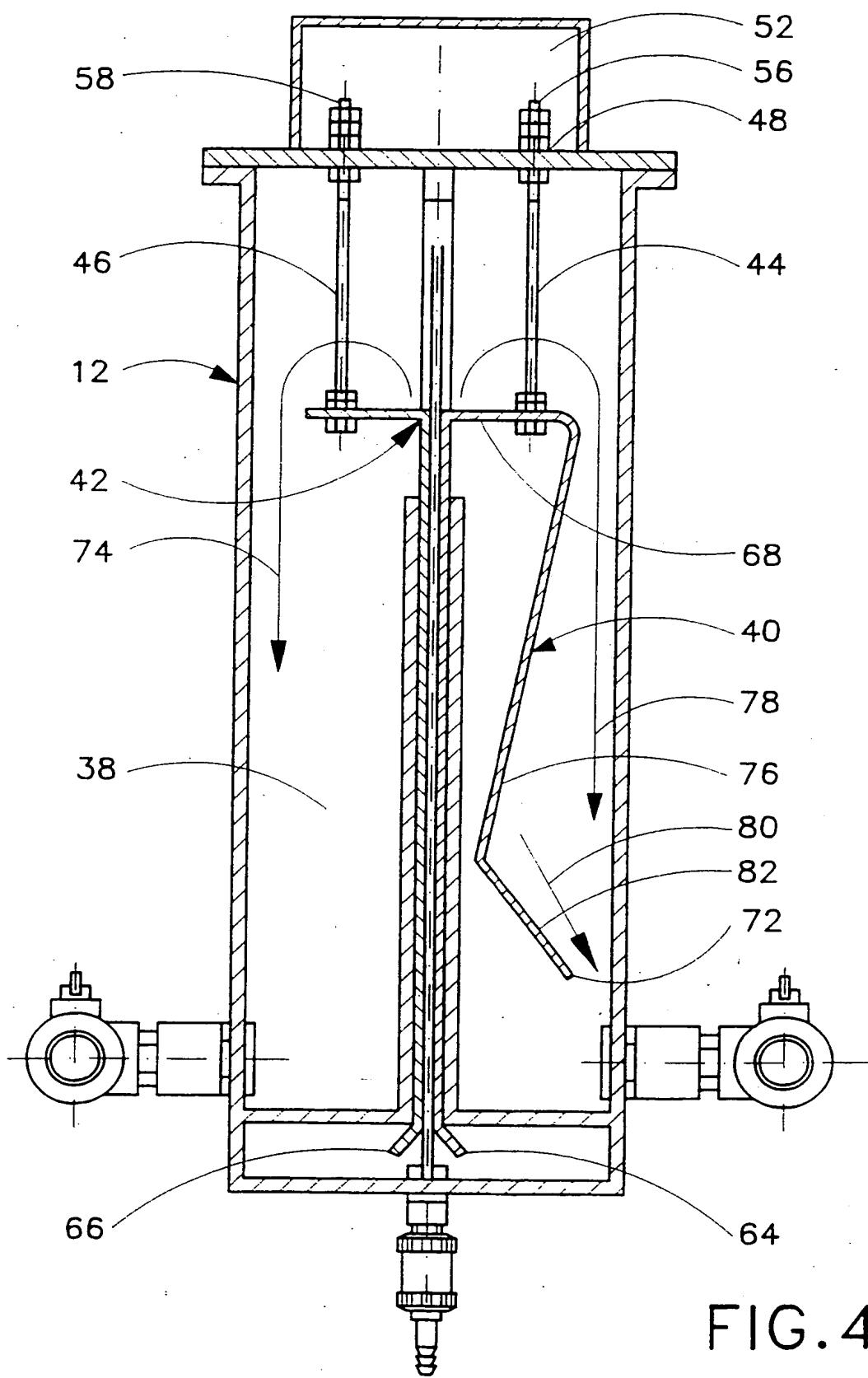


FIG. 4

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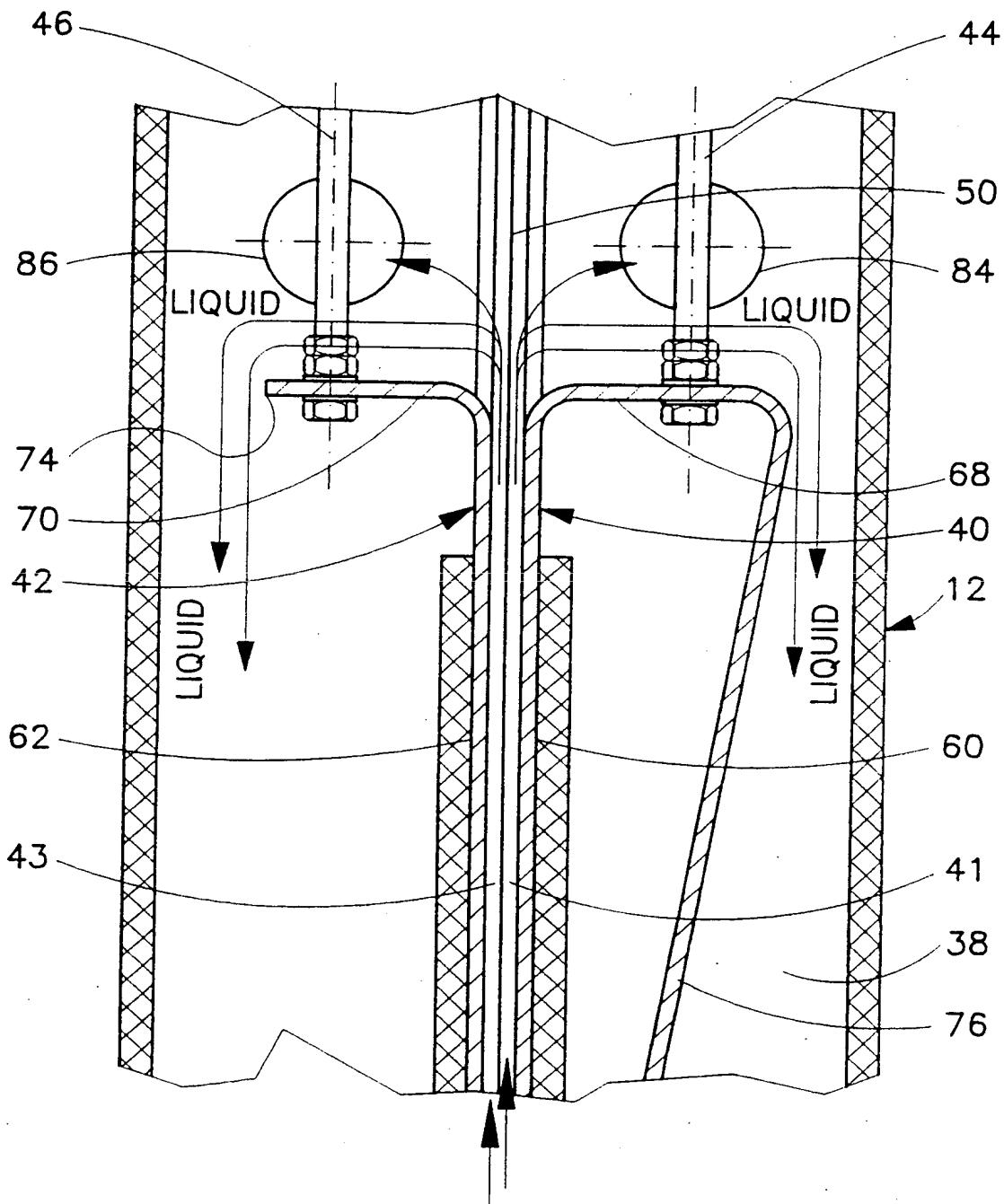


FIG.5

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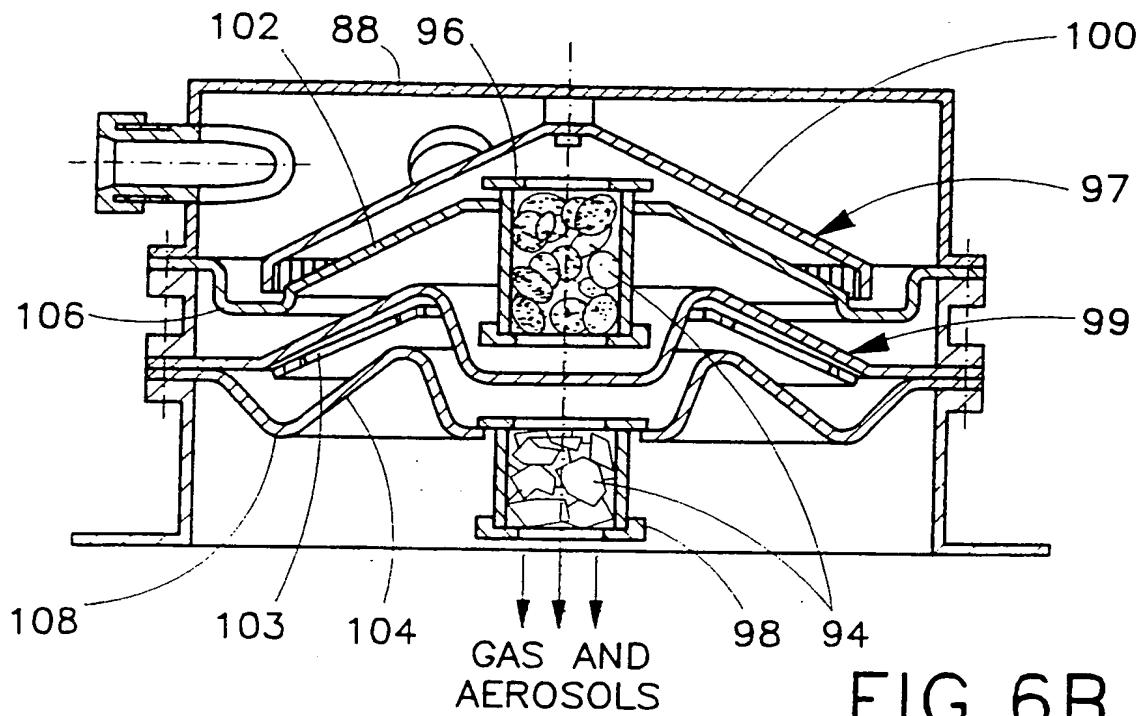


FIG. 6B

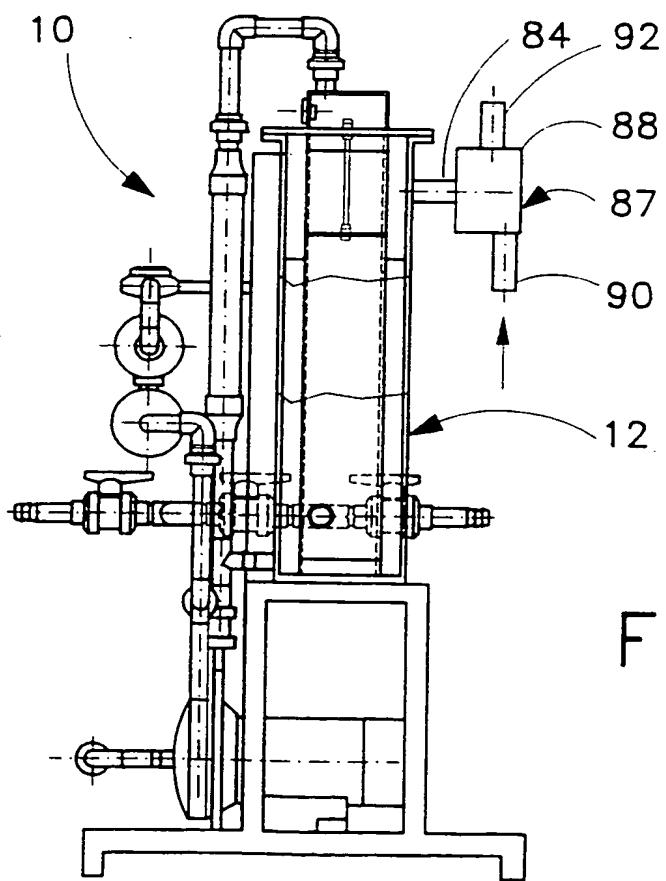


FIG. 6A

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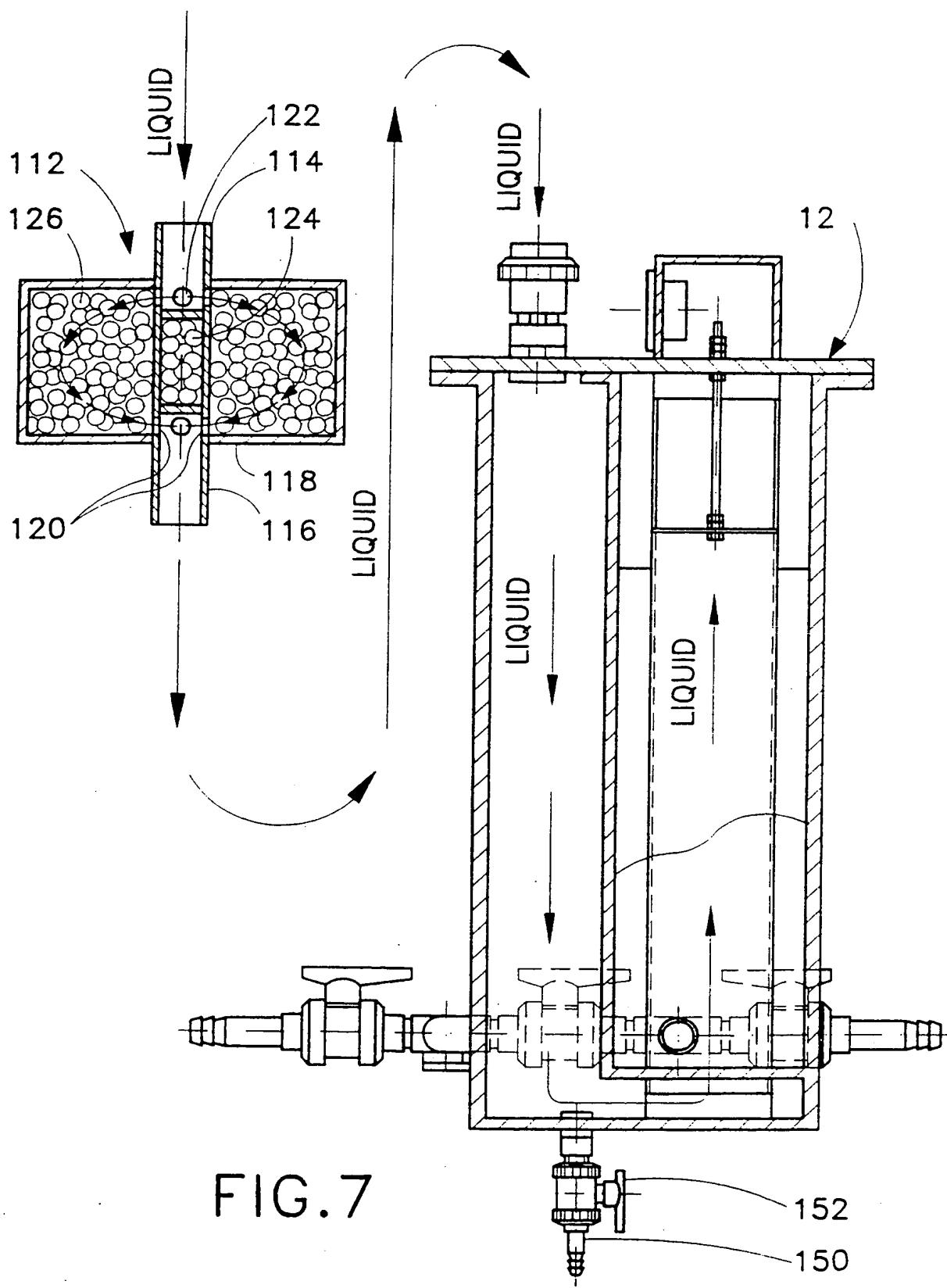


FIG. 7

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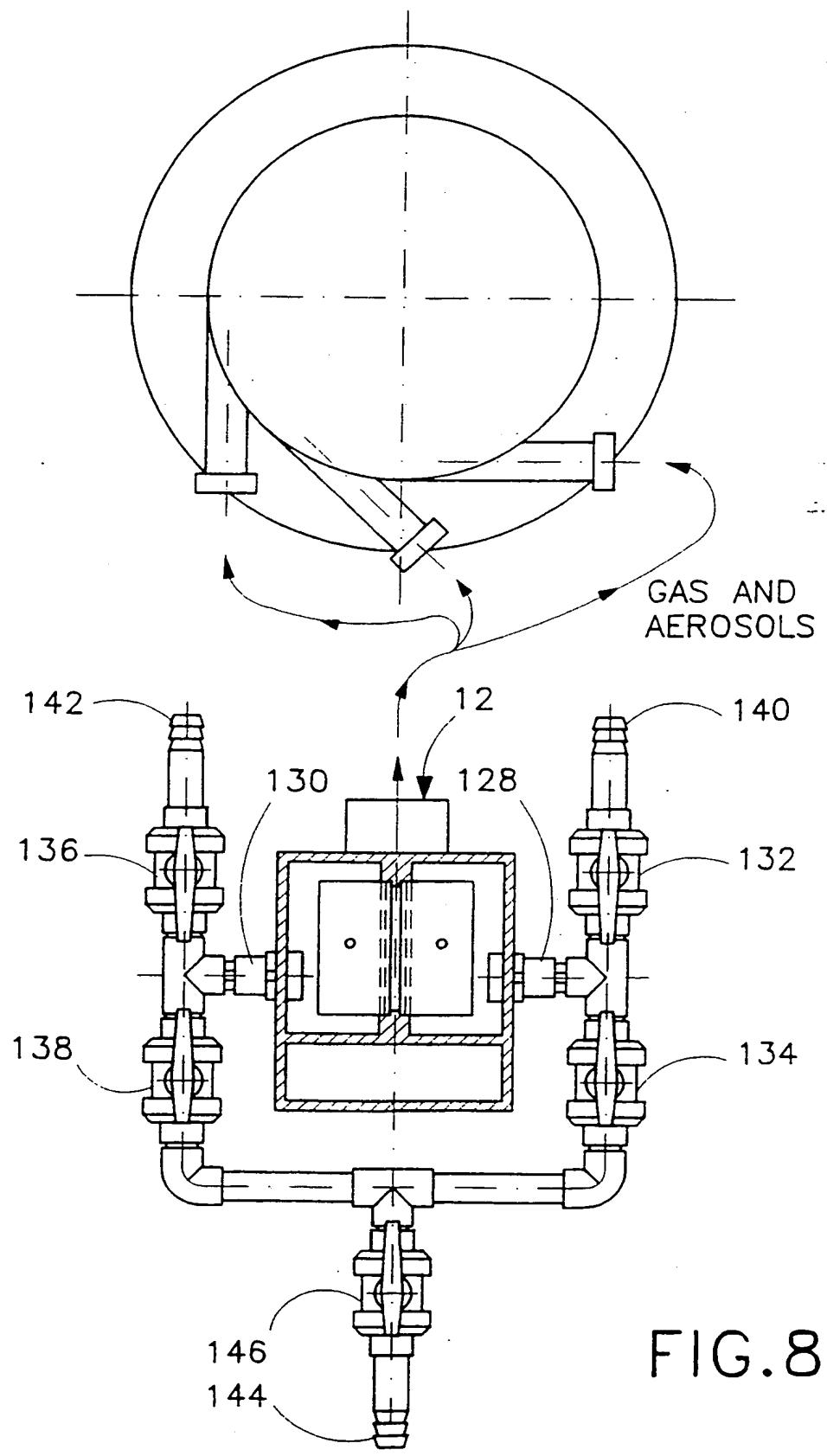
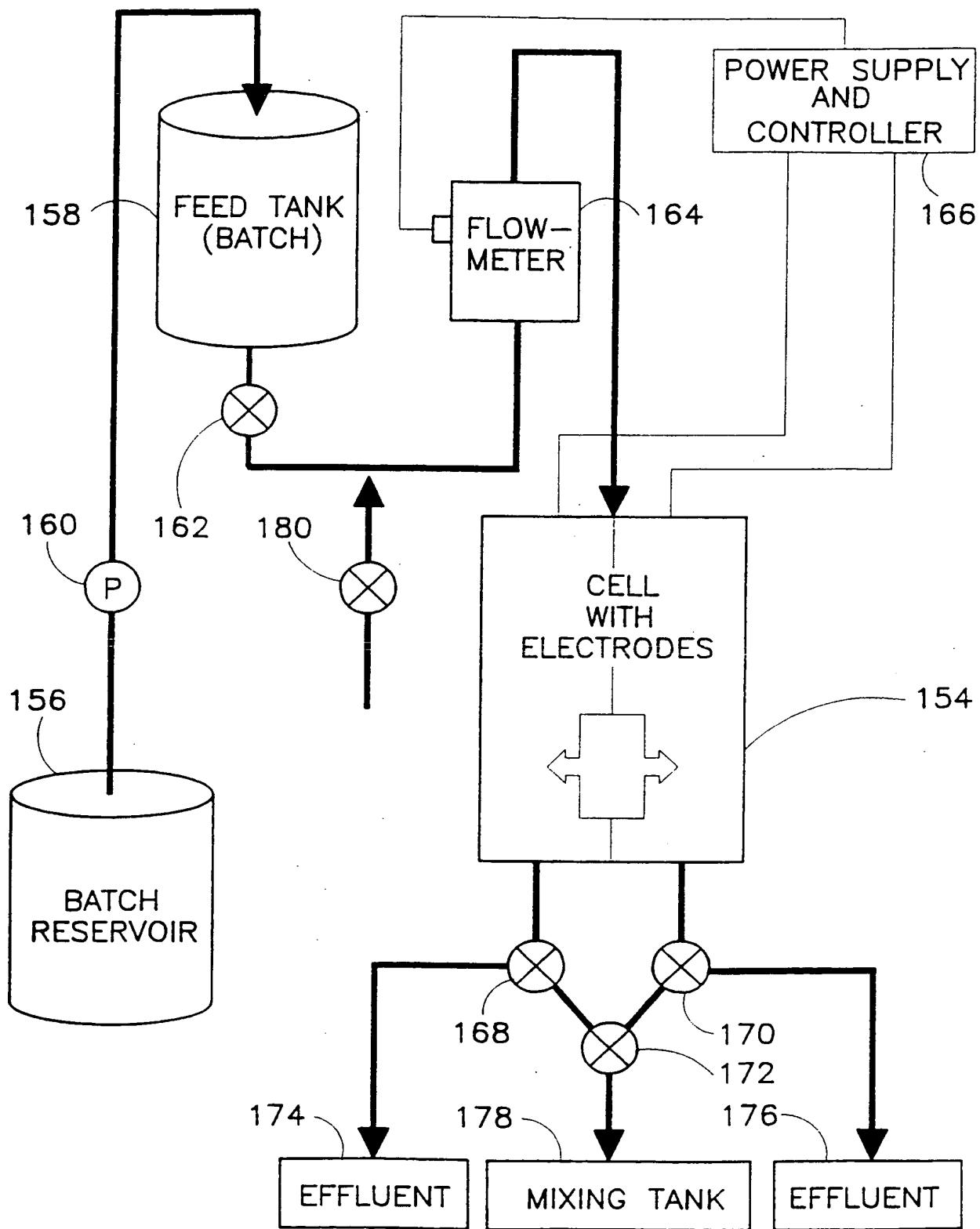


FIG.8

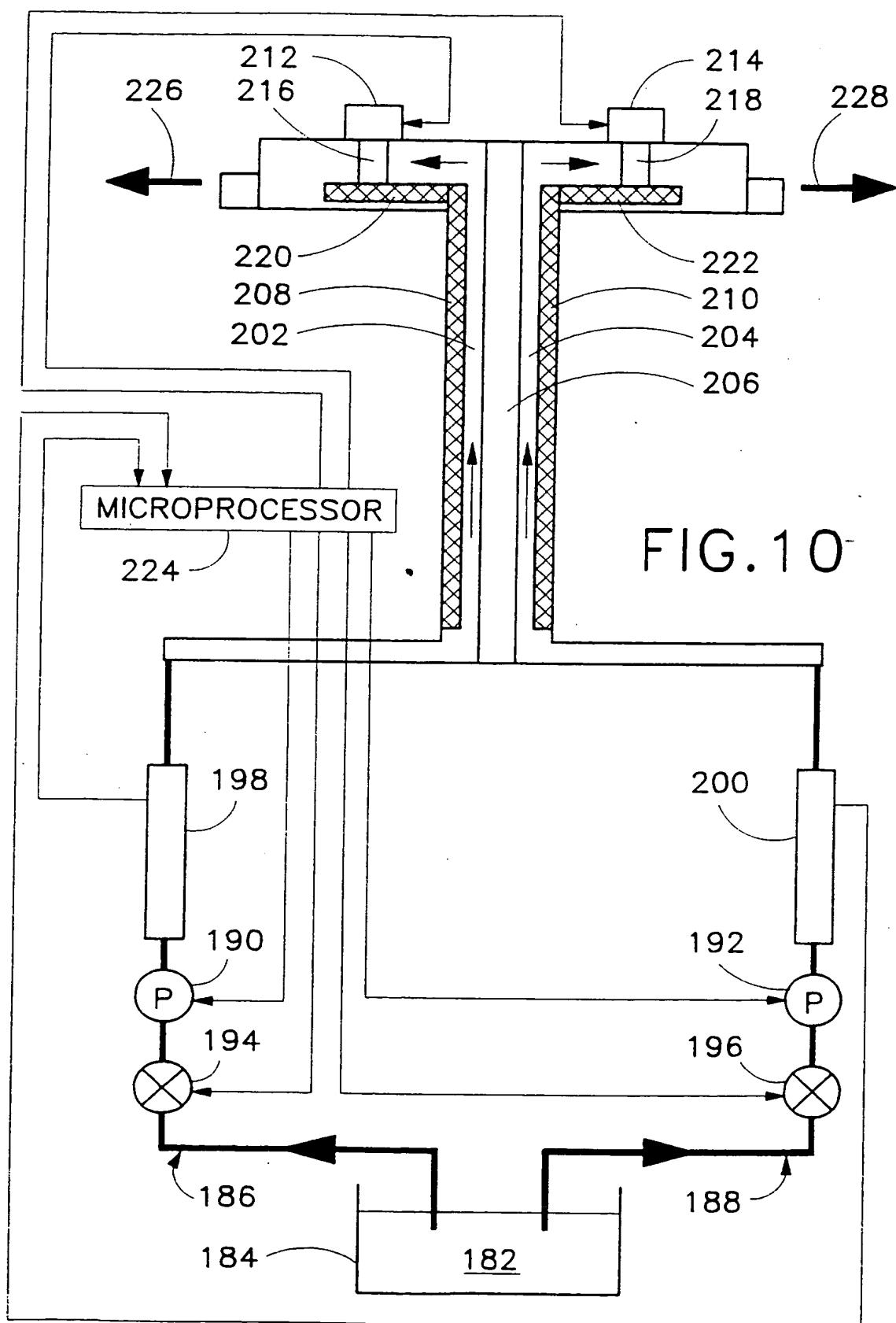
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**FIG.9**  
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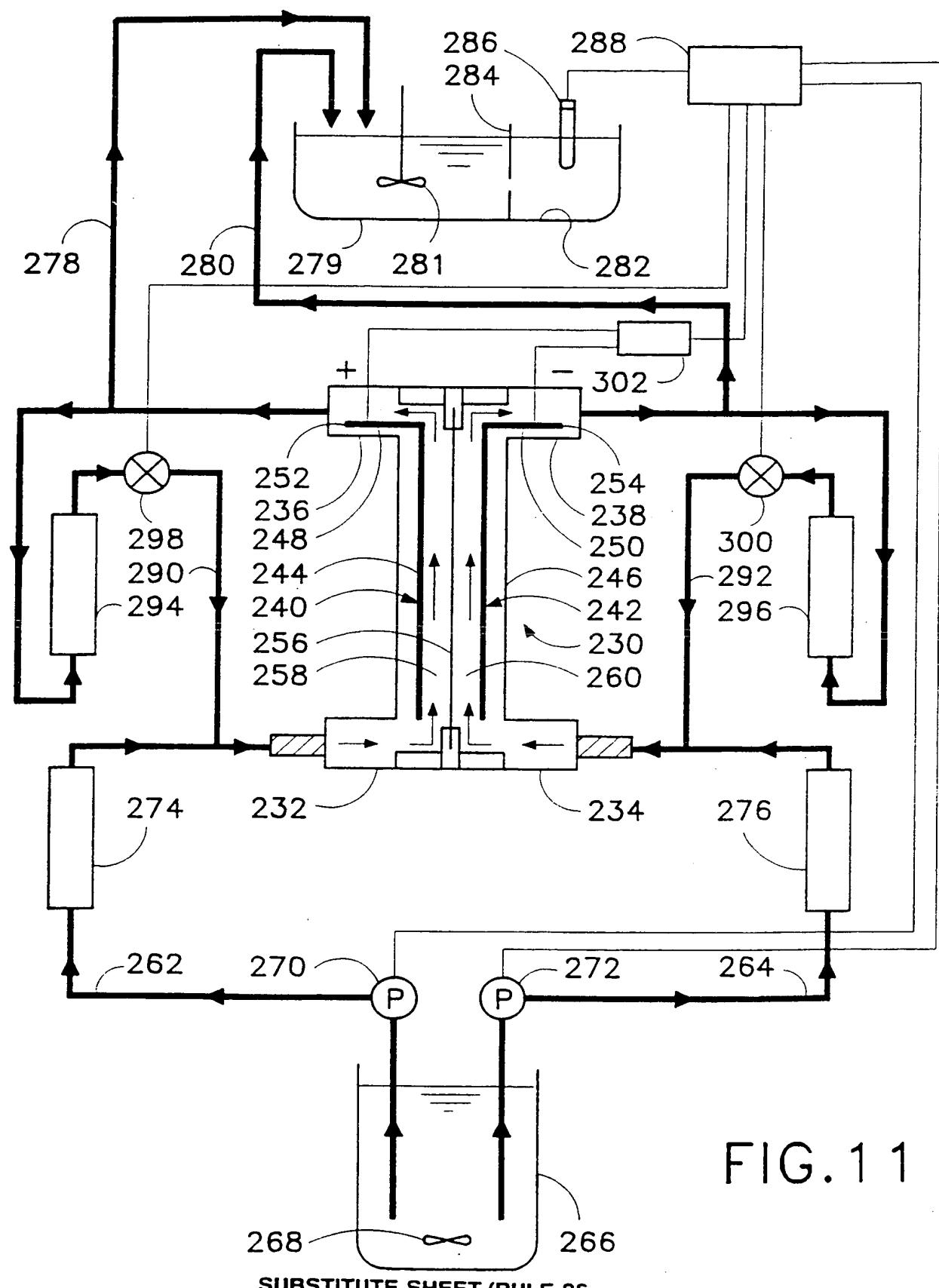


FIG. 11

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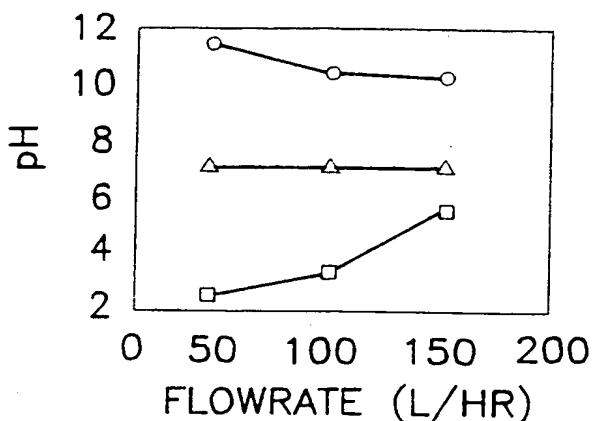
pH VS. FLOWRATE

FIG. 12A

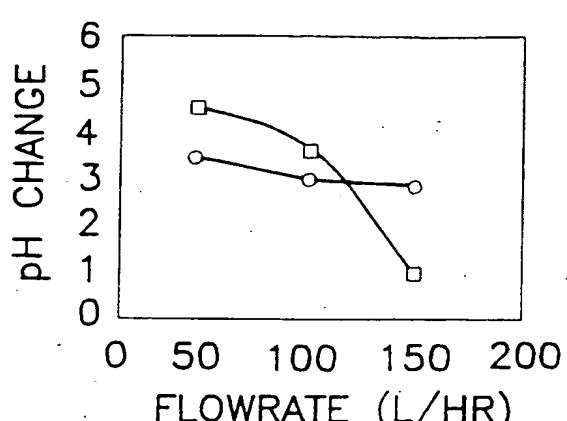
pH CHANGE VS. FLOWRATE

FIG. 12B

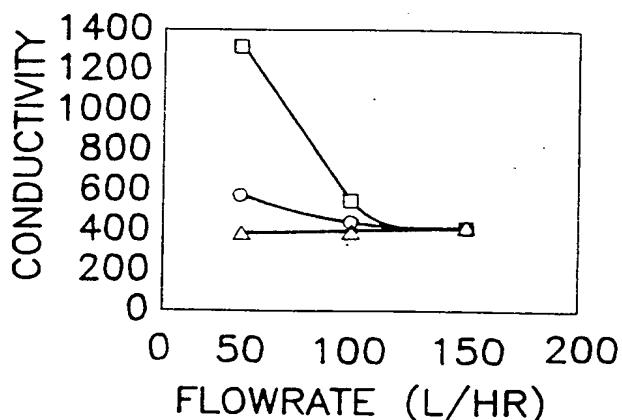
CONDUCTIVITY VS. FLOWRATE

FIG. 12C

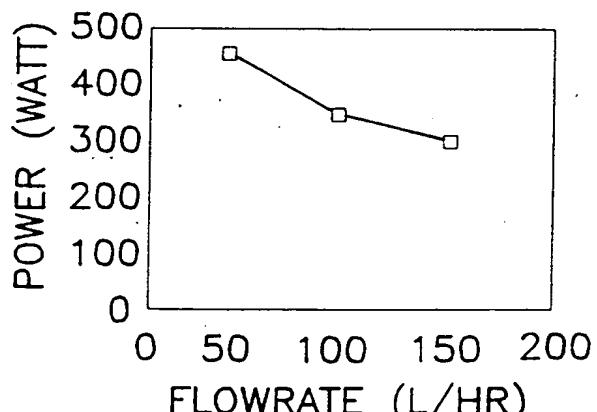
POWER VS. FLOWRATE

FIG. 12D

LEGEND

- ACID SIDE
- BASE SIDE
- △— INFLUENT

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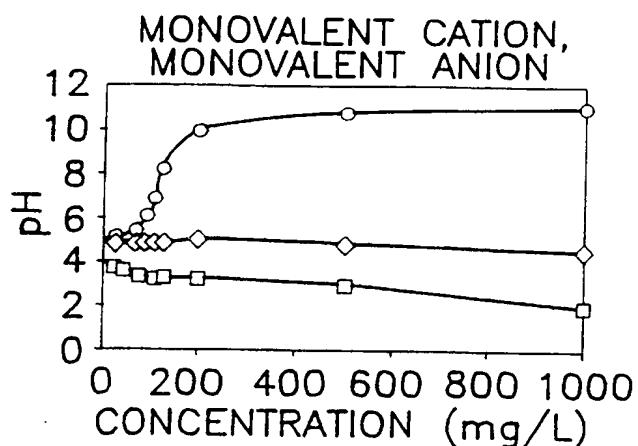


FIG. 13A

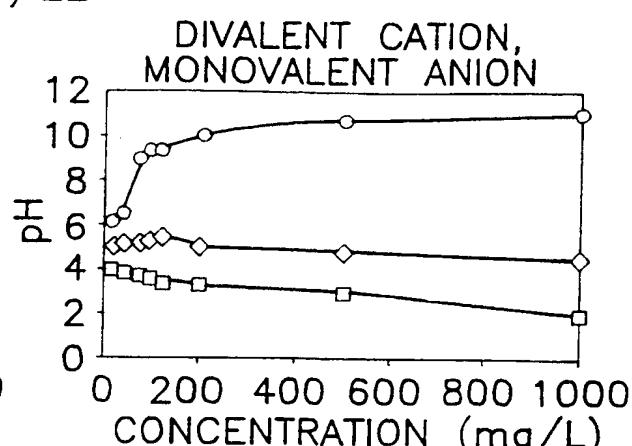


FIG. 13B

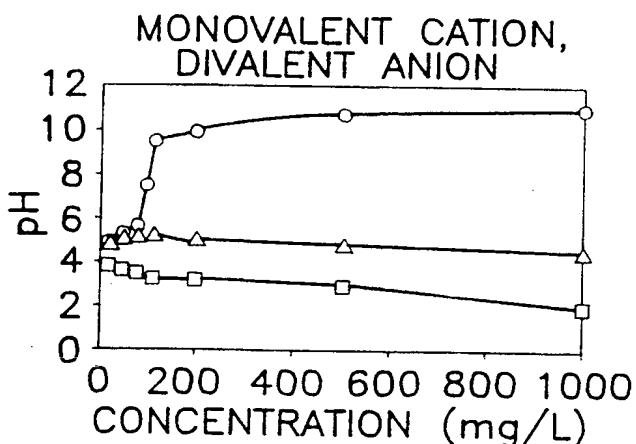


FIG. 13C

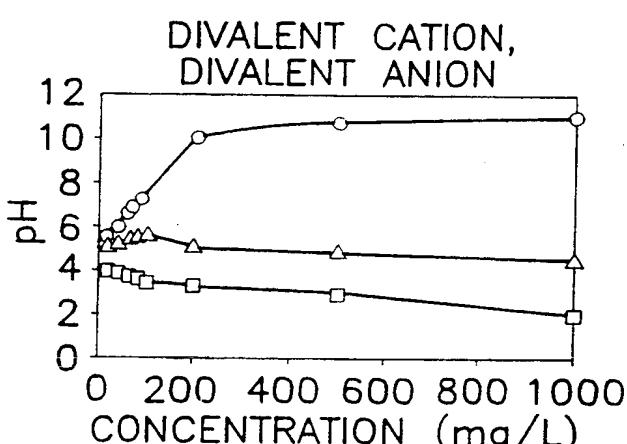


FIG. 13D

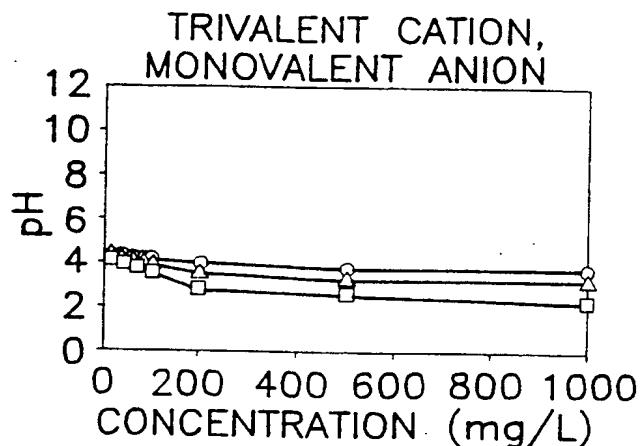


FIG. 13E

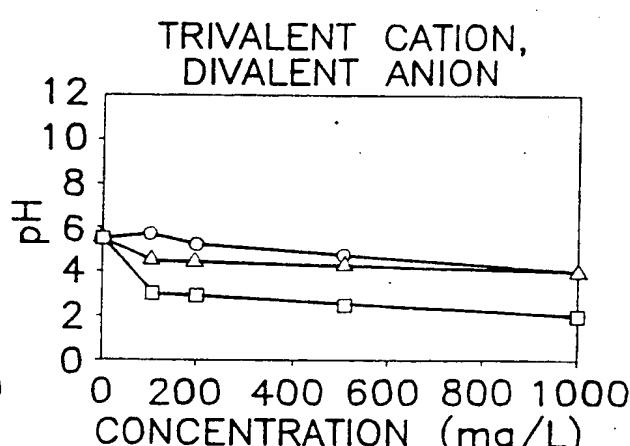


FIG. 13F

LEGEND

- ACID
- BASE
- △— INFLUENT
- ◇— INITIAL

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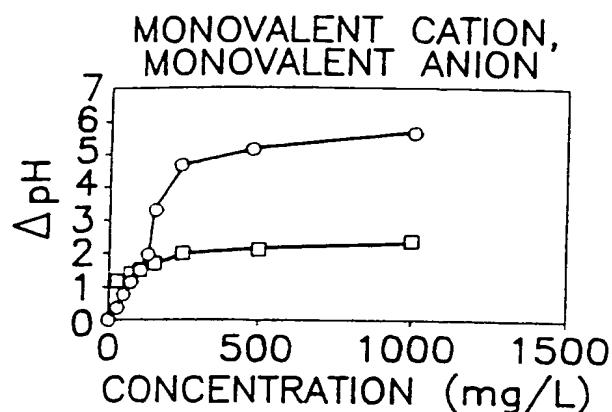


FIG. 14A

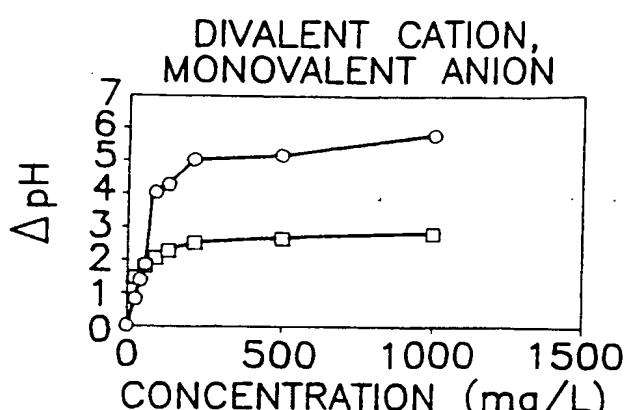


FIG. 14B

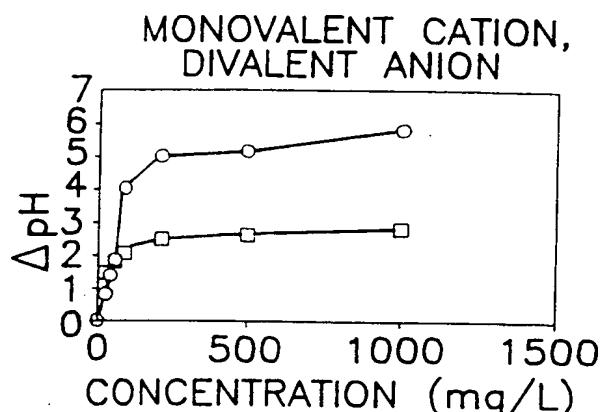


FIG. 14C

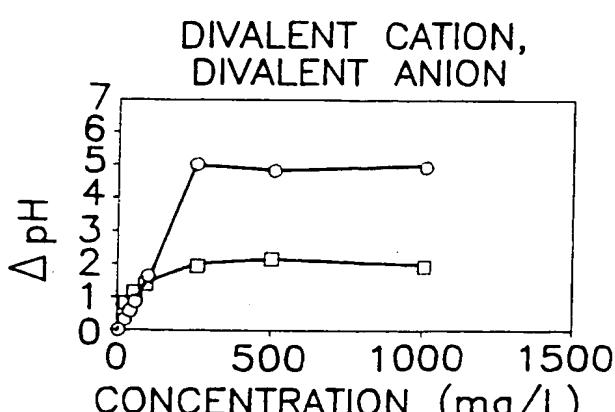


FIG. 14D

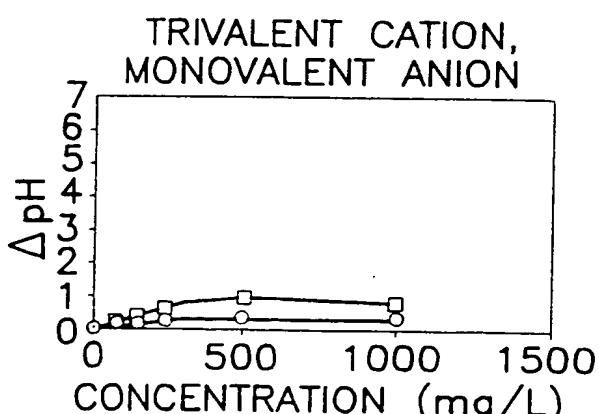


FIG. 14E

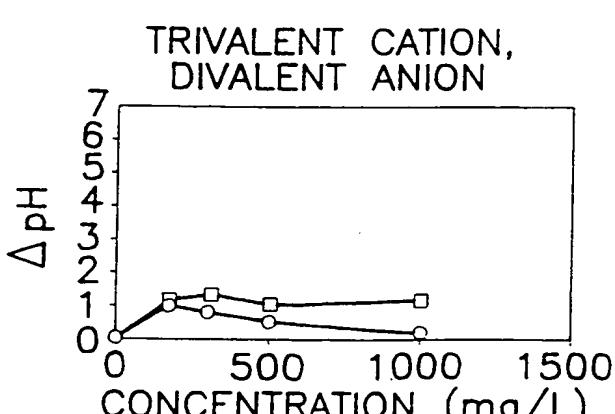


FIG. 14F

LEGEND

—□— ACID  
—○— BASE

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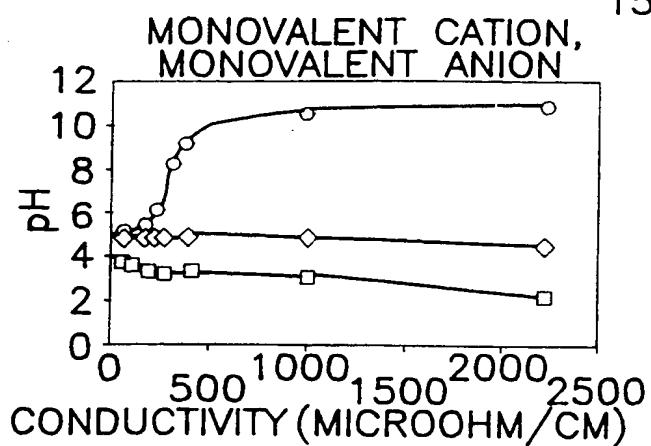


FIG. 15A

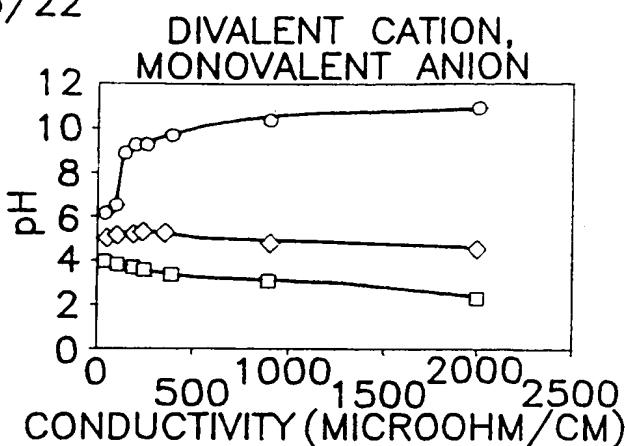


FIG. 15B

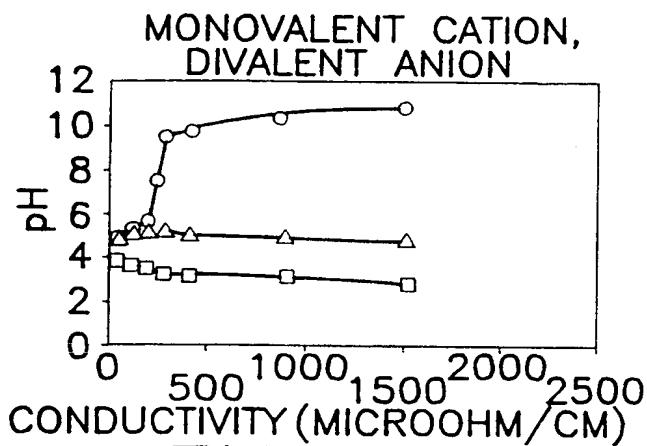


FIG. 15C

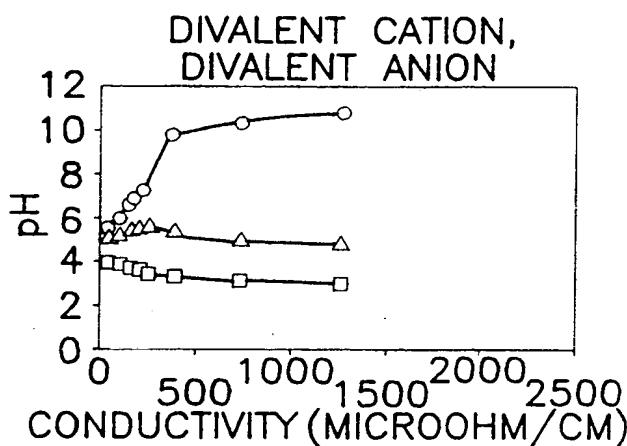


FIG. 15D

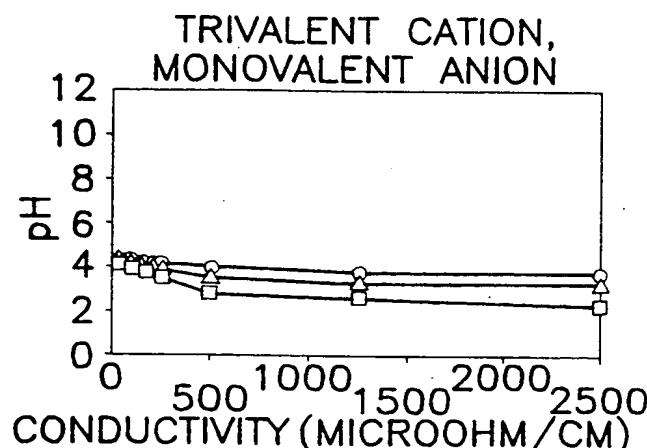


FIG. 15E

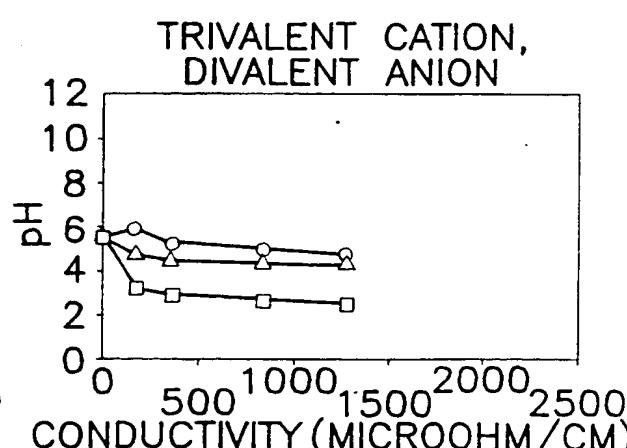


FIG. 15F

LEGEND

- ACID
- BASE
- △— INFLUENT
- ◇— INITIAL

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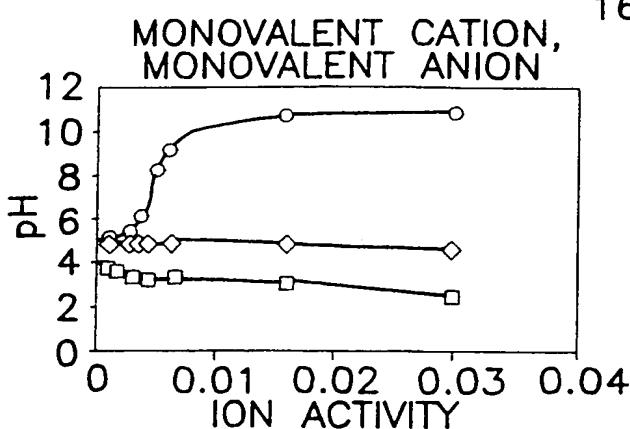


FIG. 16A

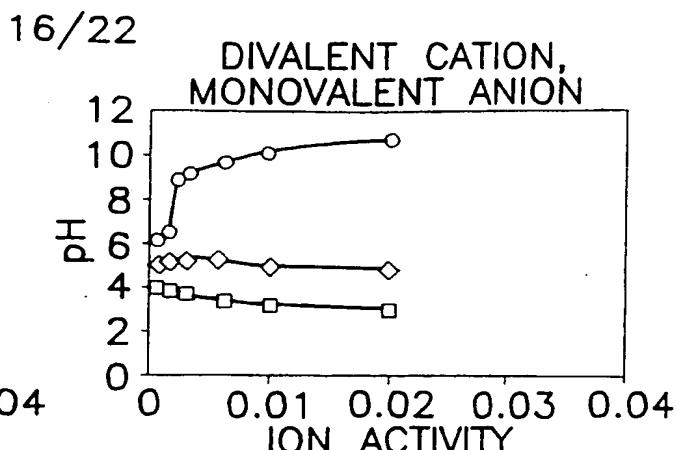


FIG. 16B

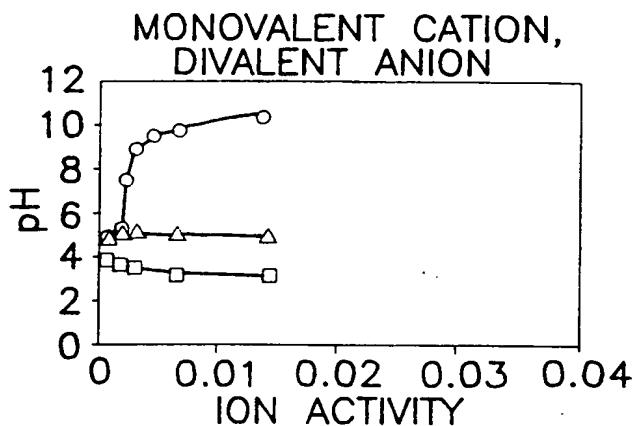


FIG. 16C

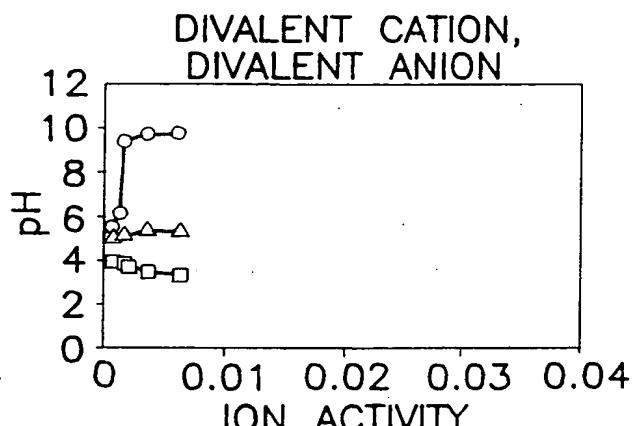


FIG. 16D

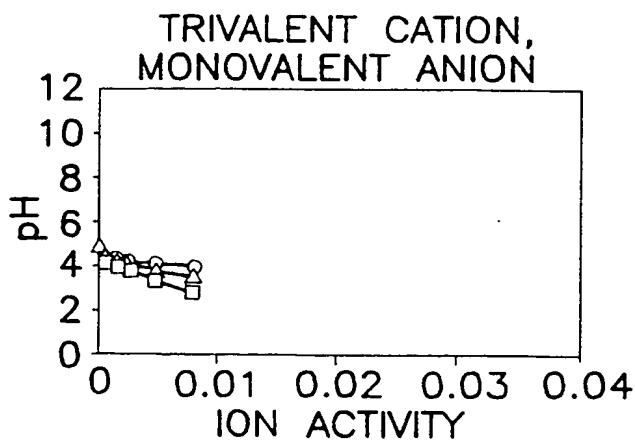


FIG. 16E

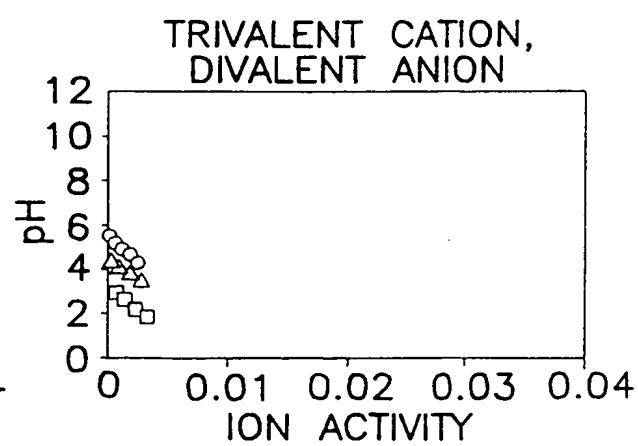


FIG. 16F

LEGEND

- ACID
- BASE
- △— INFLUENT
- ◇— INITIAL

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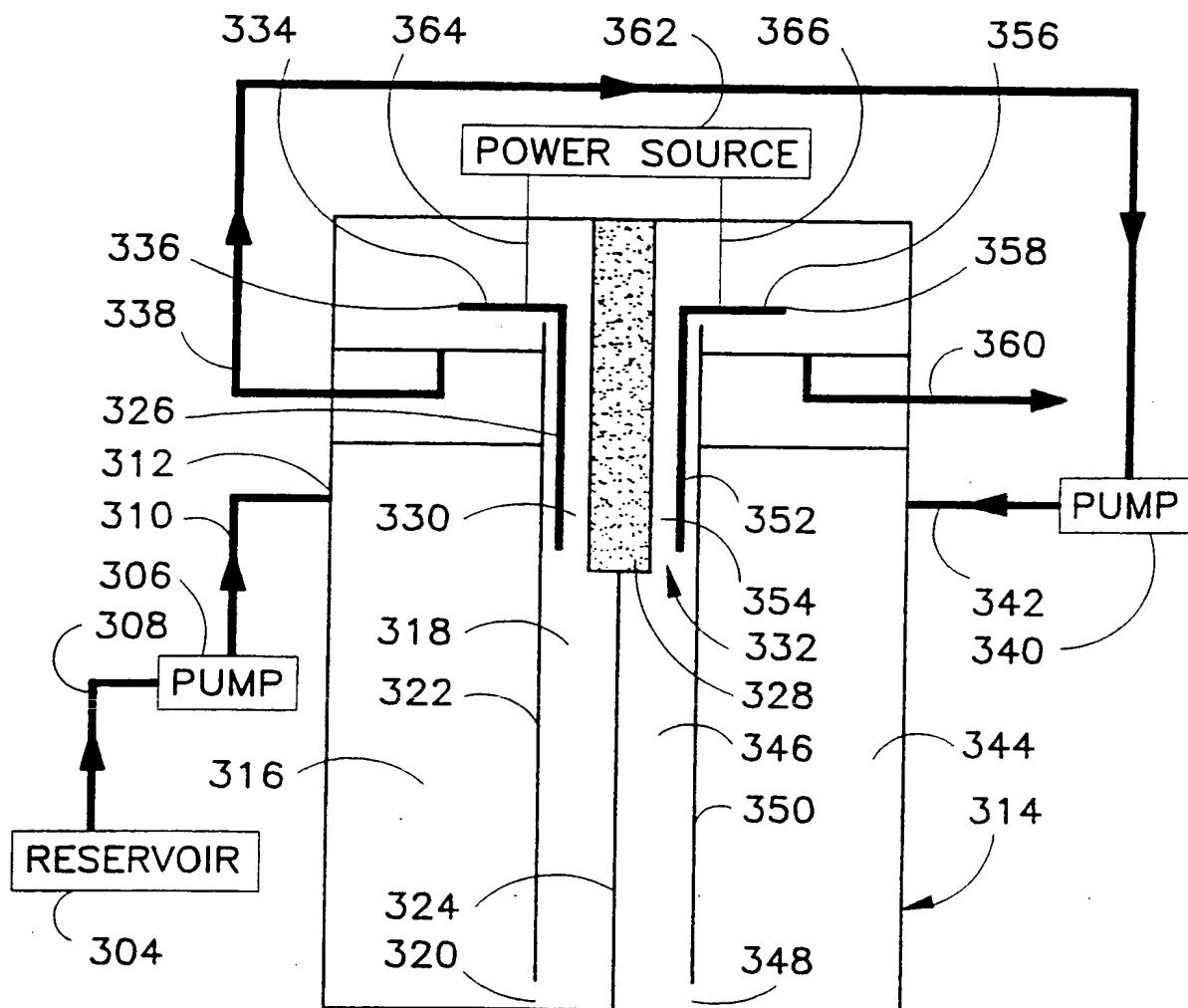
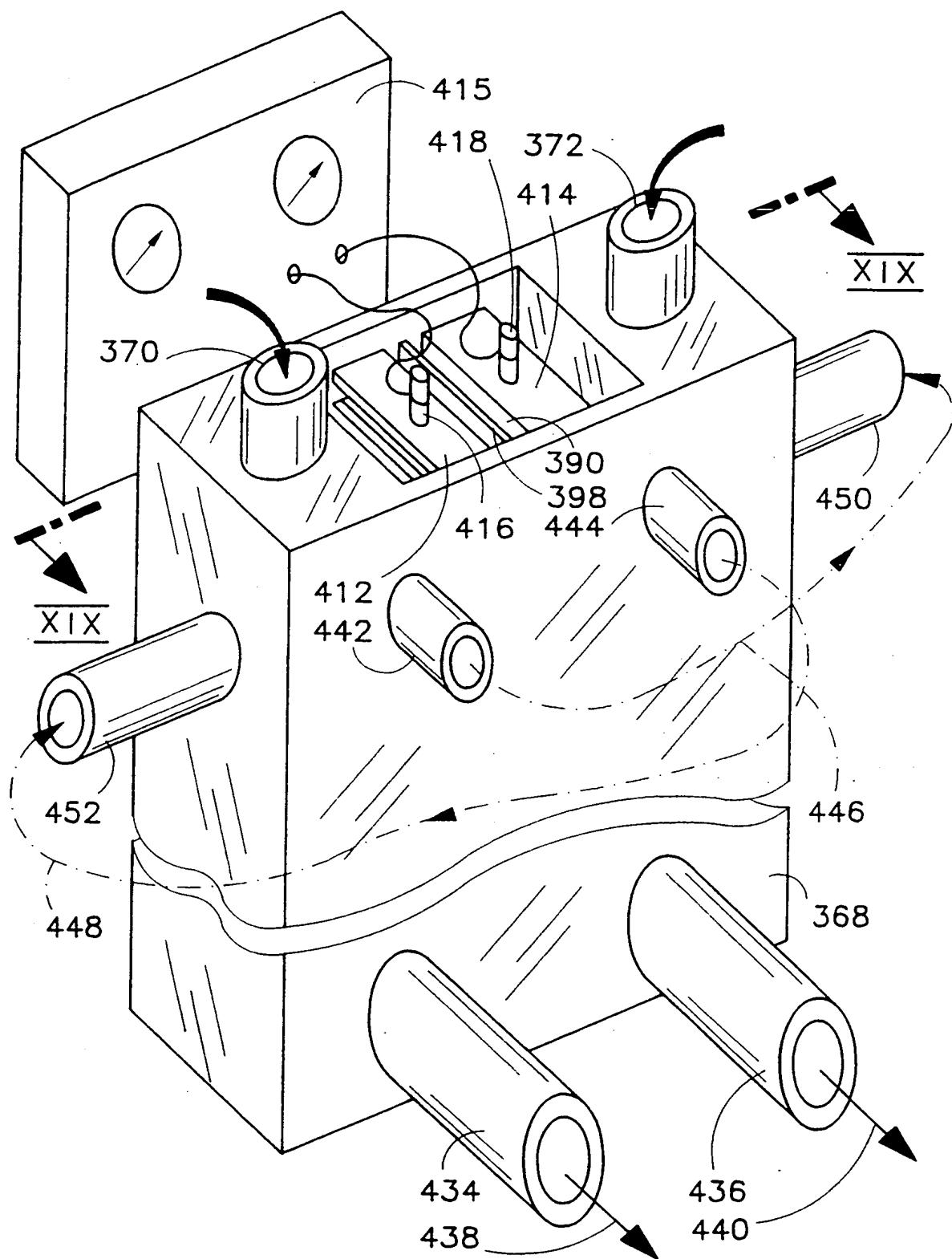


FIG. 17

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**FIG. 18**  
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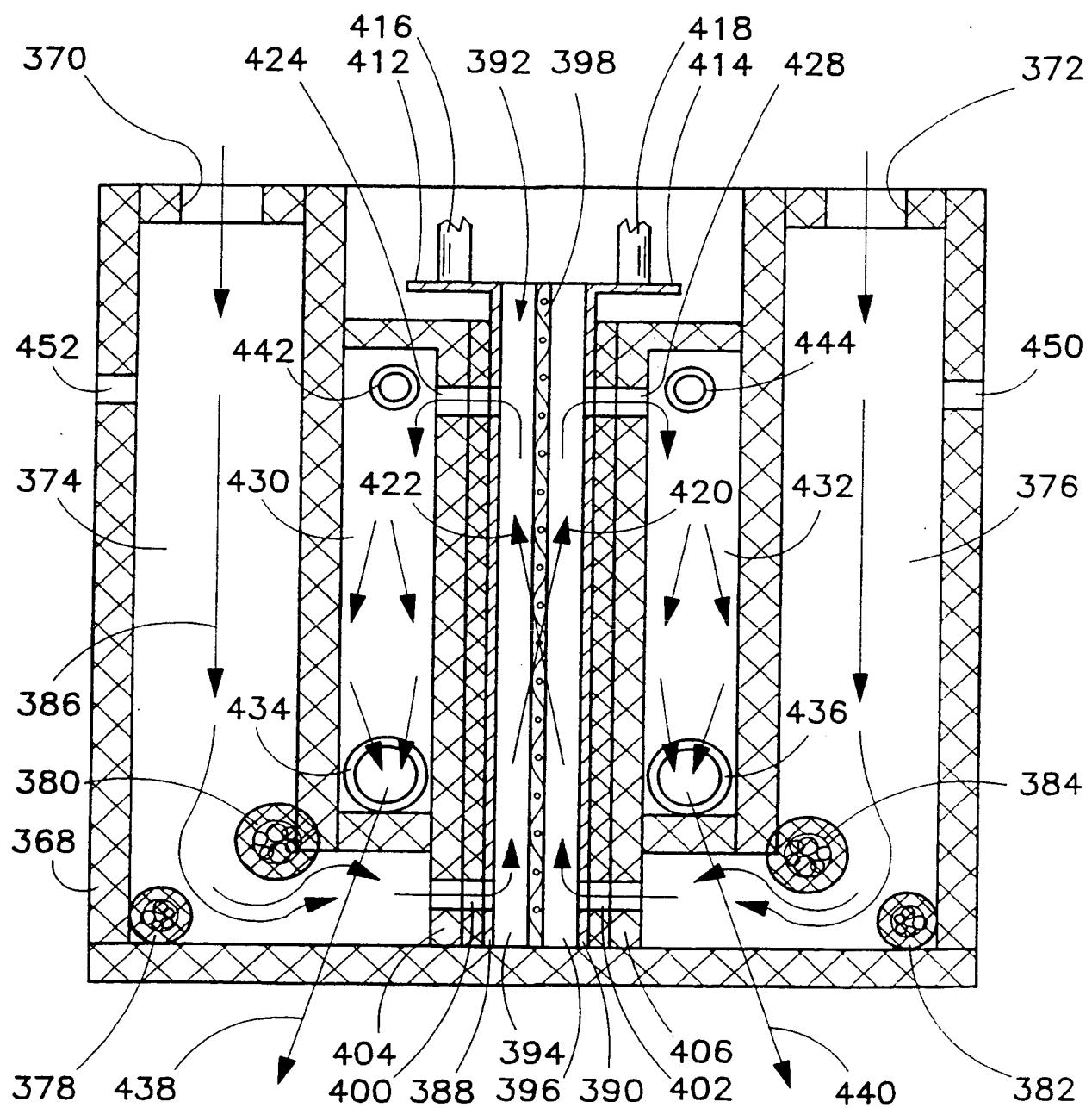


FIG. 19

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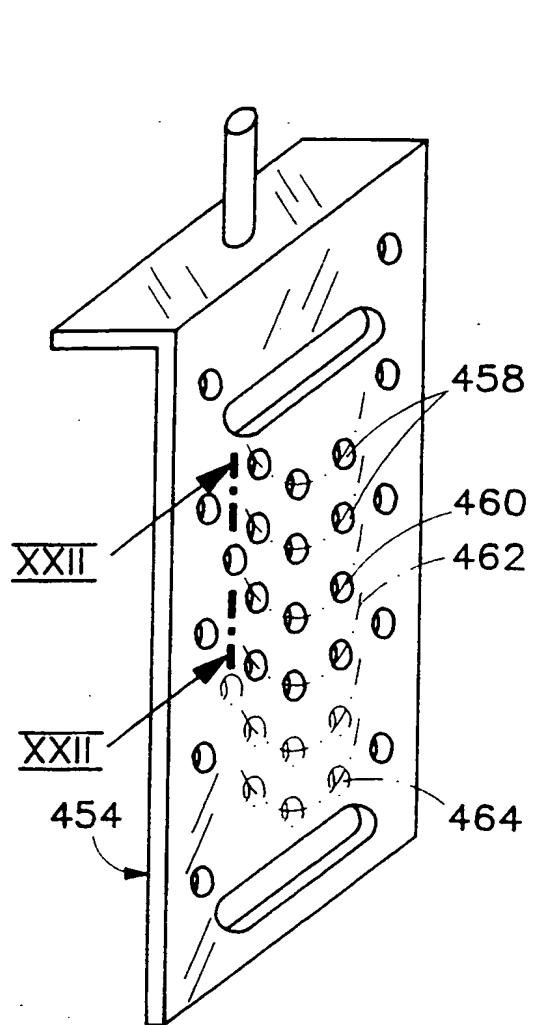


FIG. 21

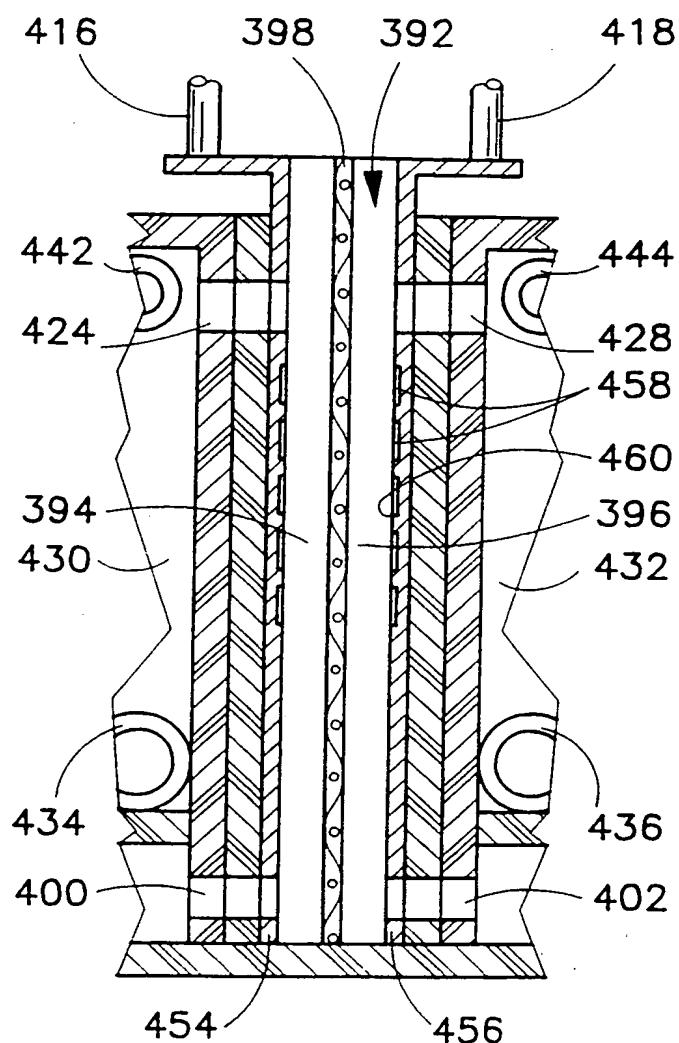


FIG. 20

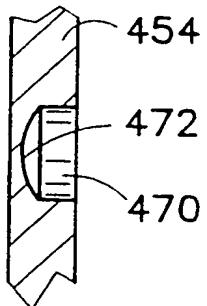


FIG. 24

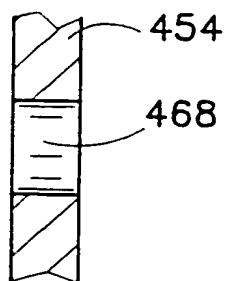


FIG. 23

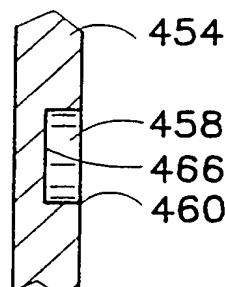


FIG. 22

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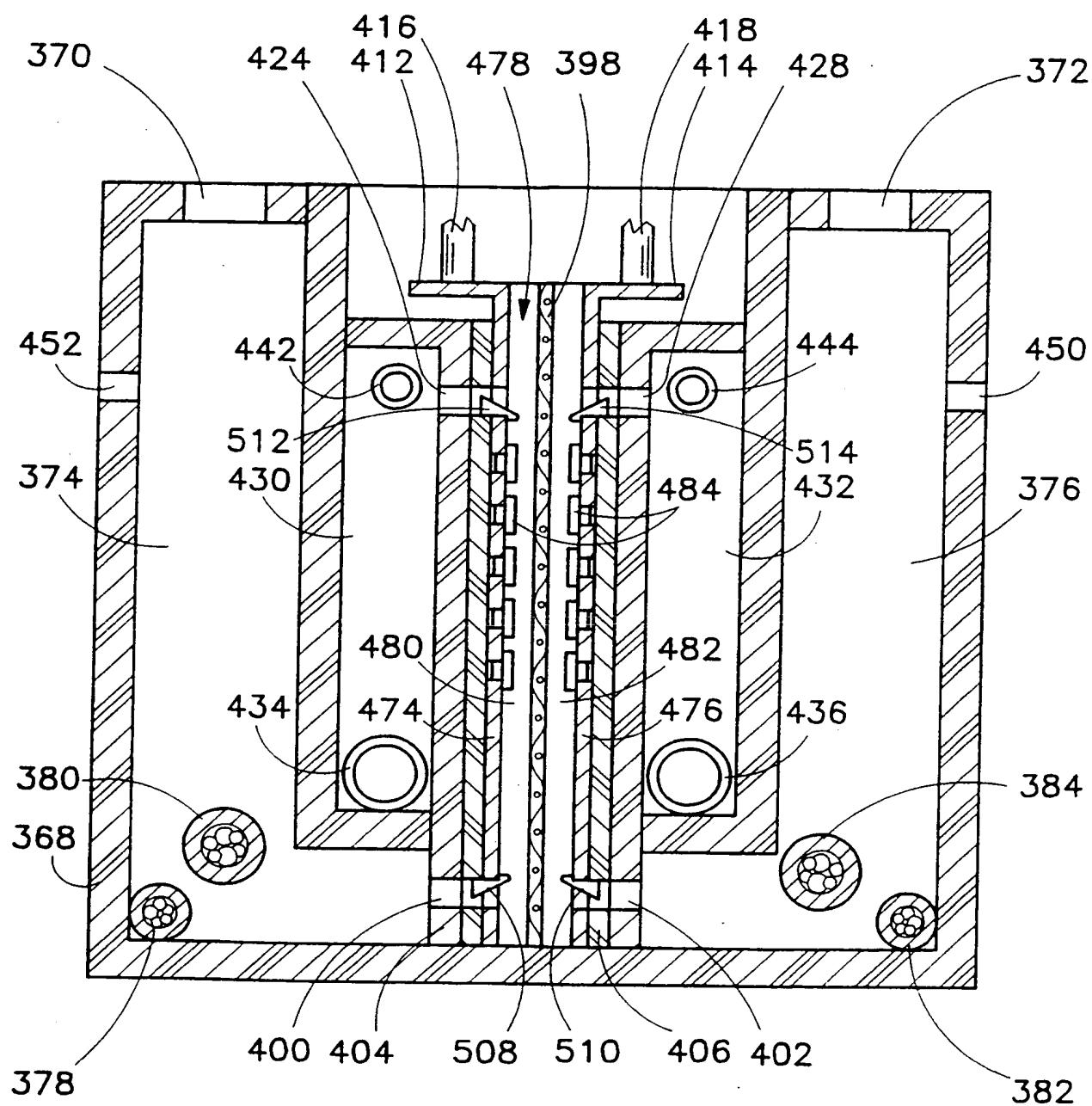


FIG. 25

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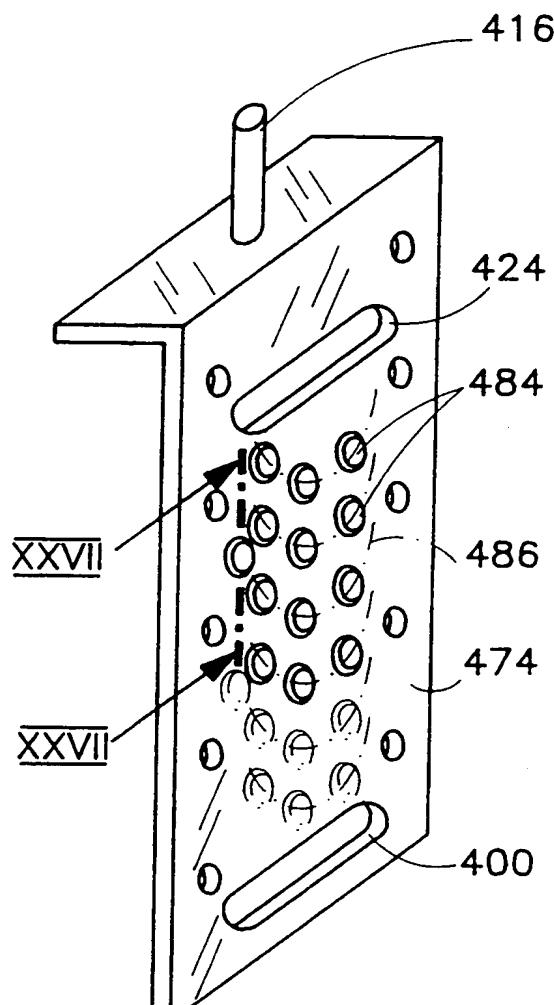


FIG. 26

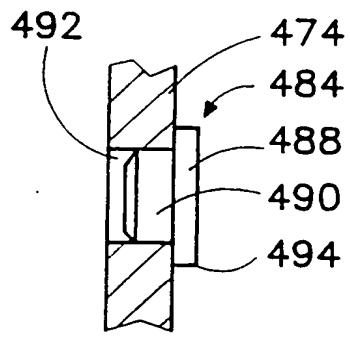


FIG. 27

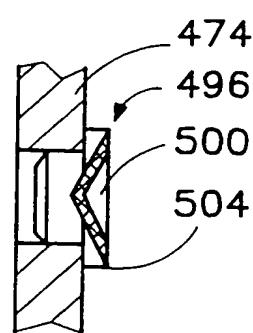


FIG. 28

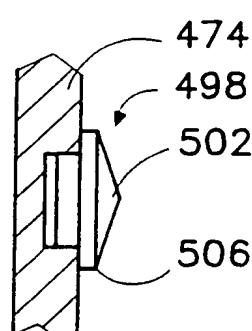


FIG. 29

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**INTERNATIONAL SEARCH REPORT**

International application No. PCT/US98/25114
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**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :CO2F 1/461, 1/469

US CL : 205/703, 746, 747, 751, 770; 204/518, 263, 264, 266, 627

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 205/703, 746, 747, 751, 770; 204/518, 263, 264, 266, 627

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,374,714 A (HEKAL) 22 FEBRUARY 1983, SEE CLAIMS 1-11.	1-94
Y	US 4,857,343 A (HEKAL) 15 AUGUST 1989 SEE CLAIM 1-9.	1-94

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

22 FEBRUARY 1999

Date of mailing of the international search report

03 MAR 1999

Name and mailing address of the ISA/US  
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Box PCT  
Washington, D.C. 20231

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Telephone No. (703) 308-0661